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THE COLLECTION OF CATCH AND EFFORT STATISTICS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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ABSTRACT

The circular starts by describing the role of catch and effort statistics in fisheries studies. For comparability between statistics collected from different areas standard terminologies for catch and landings and their sub-divisions by species, method of capture, area of capture, etc. are proposed. Similarly, measures of fishing effort as used in different types of fishery are explained. This is followed by a detailed discussion of the planning of a catch-effort survey, including sampling designs, methods of collection of data and appropriate estimation procedures. Two case studies are included to illustrate survey designs frequently employed. A detailed Appendix is provided on basic sampling theory and sampling designs, giving numerous numerical practical examples from various types of catch-effort surveys.

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1. Purpose of collecting catch and effort statistics

A variety of mathematical models are available for the assessment of the status of a fishery. The more elaborate analytical models require statistics on a number of variables such as catch, effort, age, growth-rate, mortality-rate, etc. It is always difficult to obtain reliable statistics on so many items. Fortunately, simpler assessment models exist requiring only catch and effort statistics. Thus, catch and effort statistics constitute the minimum requirements for a simple assessment of a fishery.

Catch statistics alone are not enough to describe the impact of a fishery on the exploited resources. To take an example, let us suppose that the catch from a fishery increases from 20 000 metric tons (t) in one year to 40 000 t in the next. Now this increase in catch may be either due to an increase in fishing effort alone or may be entirely due to increased abundance of fish or may be due to simultaneous changes in both abundance and effort. Without fishing effort statistics, it will not be possible to explain which of the above situations is responsible for the increase in catch. There is still another possibility that the increase in catch may not be due to changes in fish abundance or fishing effort, but due to environmental changes making a larger portion of the resource available for fishing. This is an exceptional situation and may be detected as an aberrant based on other biological and oceanographical information (e.g. sardines concentrating near the beach due to low oxygen levels offshore caused by upwelling).

A "good measure" of fishing effort is directly related to the fishing mortality rate, an estimate of which is needed in some of the more elaborate resource assessment models referred to earlier. Statistics of fishing effort are therefore crucial to fishery scientists making resource assessments. Criteria for distinguishing "good" or "bad" measures of fishing effort are discussed later.

Catch-per-unit effort is an index of abundance and level of exploitation of a fishery resource. In conjunction with the estimated total yield from an exploited stock, it is used to determine the number of boats that the fishery may be expected to support. Catch-per-unit-effort is also used to investigate the availability of fish. Availability is a general term used to describe the degree to which a fish stock is vulnerable to capture, and may vary on a daily or seasonal basis. An example of diurnal change in availability is provided by the gill net fishery. Very few fishes are caught in gill nets during daylight, most are being caught at night. The reason for this is that a fish has to swim into a gill net to be caught. During the day, most fish species are either not active or are able to detect the net and therefore do not get caught, i.e. they are not available to the gear. Thus, catch per gill net from day hauls does not reflect the true availability of the fish. An example of the seasonal change in availability is provided by fisheries based on fish which migrate outside the range of local fishing fleets, e.g. outside the area that can be covered by sailing boats making day trips. The data on seasonal and daily variations in availability in terms of catch-per-unit effort are very important elements in resource surveys and feasibility studies. It would be disastrous if a fishery was developed on the basis of high catch-per-unit-effort based on three months survey work, and the assumption that the catch-per-unit-effort would be the same during the whole year, when in fact fish were not available or vulnerable to capture in the other nine months of the year.

Catch and fishing effort statistics of commercial or test fishing operations are important for enterprises or governments wanting to invest in fisheries.

The fishing effort exerted represents the expense side of the operation, while the catch represents the income side of it. An owner of a fishing boat will want to know whether the value of the catch he takes will pay for the cost of running his boat and the capital invested in it. This calculation is equally necessary for the owner of a large firm having many vessels, or for an individual fisherman intending to buy a canoe, an outboard motor, or a few gill nets.

The above compilation of the uses of catch and effort statistics is not exhaustive, but only illustrates the various uses of such statistics and therefore the need for their collection.

2. Catch and landing statistics

Before taking up discussions on the planning and organization of a statistical survey for obtaining estimates of catch and effort, it will be useful to define the terms "catch" and "effort" and describe their characteristics and their relation to other terms used to signify similar concepts.

2.1 Definitions

The terms "catch" and "landing" are often used loosely as synonyms but they are not always the same. Gross catch is the total weight of fish caught by a fishing unit from the sea. If all the fish caught by a fishing unit are landed ashore as whole fish, the weight of landings and gross catch are the same. This is usually the case in respect of artisanal inshore fisheries in developing countries where the fishermen fish in waters close to the shore and land whatever they catch. But in many cases the quantity landed is not the same as the gross catch. A part of the gross catch may be discarded at sea for various reasons. If in a particular country certain species or small-sized fish are not accepted by consumers and cannot be sold, the fishermen will naturally sort them out on board the vessels and discard them at sea. Sometimes small fish of certain species are discarded because of legal restrictions in catching them. Fishermen may also use a part of the gross catch for their own consumption. In shrimp trawl fisheries usually the low value by-catch is thrown away because the limited holding space is needed for high value shrimps.

Apart from discards, vessels fishing for a longer duration generally process a part of the gross catch on board. Examples of processed catches are gutted, filleted, frozen, salted, dried fish, headed shrimp/lobster, boiled shrimp, fish meal and oil. As a consequence of the varied practices described above, the weight of landings is generally less and sometimes considerable less than the gross catch, while it is likely that information on landings will be in several different forms depending on the vessel. Some vessels will land their fish gutted, others filleted or dried or salted and still others whole. The same species of fish may be landed in different ways even in the same port. Unless a standard procedure is adopted for reporting, it will be impossible to compare data from different sources and to combine them when necessary. For this reason, international fishery bodies have drawn up a list of basic definitions of catches and landings, as shown in Table 1, which should be strictly followed to avoid confusion. The FAO and most fishery commissions and bodies require catch data in the form of "nominal catch" as defined in Table 1 (FAO, 1976) and illustrated in Figure 1.

2.2 Conversion of landed weight to normal catch

Since it is usually required that reporting be done in terms of nominal catch, it is necessary to convert landed weight to nominal catch. This is done by use of conversion factors or conversion tables. Such conversion tables or factors for each species group are usually made ready at the time of planning a survey for catch and effort statistics or should become available during the execution of the survey. By using the appropriate conversion factor or conversion table, the weight of fish landed in one form can easily be converted to the nominal catch. For obtaining conversion factors for gutted fish of a particular species, the weights of a sufficiently large number of whole ungutted fish are taken over the entire range of its exploited size, so that there are at least 10-20 observations in each size group. Each of these fish are then gutted in the standard commercial fashion. The assistance of a commercial operator in this exercise is very desirable. The weights of ungutted fish (y) against the corresponding weight of gutted fish (x) are then plotted in a graph. If a linear regression passing through the origin, i.e. $y = bx$ can be fitted to the scatter of points, then the slope of the regression line or regression coefficient is the appropriate conversion factor for converting the weight of landed gutted fish to that of ungutted whole fish of nominal catch. For example, in England and Wales, all round fish (cod, haddock, whiting, etc.) are landed gutted and the conversion factor used to raise gutted round fish to nominal catch is 1.2. Landings of 1 000 t of gutted cod would, therefore, be equal to 1 000 x 1.2 = 1 200 t of nominal catch of cod.

Very frequently it is observed that the relation between the weight of whole fish (y) and the corresponding weight (x) of processed fish (e.g. gutted fish) is non-linear. If an exponential relation $y = e^{bx}$ holds good, it can be converted to the linear form $\log_e y = bx$, and b obtained from the linear fit of $\log_e y$ and x. Thus, if the relation is found to be $\log_e y = 0.00782x$, then for 1000t of processed fish the $\log_e$ equivalent of whole fish is $0.0078 \times 1000 = 7.82$ and therefore the nominal catch is antilog$_e$ of 7.82 i.e., 2500 tons.

In the case of fish meal, dried fish or oil, a more or less similar procedure is followed. Known quantities of whole fish (y) of the species usually reduced in commercial operation are converted into one of the landed products, say fish meal, and the final weight (x) is measured. From a series of (x, y) data, the regression line y is fitted and the regression coefficient b is subsequently used as a conversion factor in converting observed weight of product (x) to estimated weight of whole fish (y).

2.3 Discarded catch

The discarded catch is "that part of the gross catch which, as a whole fish, is returned to the sea at the time of capture" (Table 1). In those countries where there are no restrictions on the size of fish which may be landed and where all species are eaten by the population or used otherwise, very few, if any, fish may be discarded at sea. In other countries where these conditions do not apply, very large quantities of fish, especially small and unwanted ones, may be discarded. This is particularly true in a shrimp fishery. Millions of small fish are caught in shrimp fisheries because these mainly take place in nursery areas for young fish. These young fish form part of the fish stock and it is very important to assess the effects of their capture. For example, would it be better to stop the shrimp fisheries in order that more young fish would enter the finfish fisheries? The answer might be "YES" if more food was required, but "NO" if the money from the sale of the shrimps was more important. Knowledge of the numbers of small commercial fish which are being caught and discarded is important for estimates of the fishing mortality. It is also an indication of the number of young fish entering the fishery each year, i.e. the recruits. At the very practical level, an exceptionally high abundance of small fish observed in a given year is one of the first signs that large numbers of young fish are or will soon be entering the fishery, and that a subsequent rise in catch-per-unit-effort can be expected.

Although it is important to know how much fish is being discarded, it is difficult to get this information. The reason for this is that fish discarded at sea do not appear in the landings. There are only two possible methods by which some information on the discards could be obtained. They are (a) the interview or enquiry method, and (b) the direct observation method. In the first method, fishermen are contacted at the landing sites when they return from a fishing trip and information on species, size and weight of fish discarded are obtained by enquiry. The limitation of this method is obvious. In spite of best intentions, the fishermen may not be able to provide sufficiently accurate data on the items of information sought. The other method involves sending trained observers on board vessels to collect the information. Since the fleet is likely to be large and each vessel makes a number of trips per year, it is impracticable and usually impossible to provide the number of observers required to cover all trips. If the data on discards are considered essential for any segment of a fishery, the only practical solution seems to be to integrate the discard survey with the catch-effort survey and restrict the observations to a sub-sample of vessels/trips selected from the samples of the main survey and get estimates of discards by appropriate estimation procedures.

2.4 Catch composition

The total catch usually consists of many species, in particular in the case of trawl fisheries in tropical waters. In many cases, the catch is sorted out either before or after landing by main species or by commercial species categories before being marketed. Sometimes, the catch is also sorted out by broad size groups within a species group. The purpose of such sorting is obviously to facilitate marketing and to increase the value, as prices of fish vary according to species and size. In other cases, only one or two groups (e.g. shrimp) are separated while the rest is landed and market unsorted.

Since most resource assessment studies are based on models dealing with a single species, fishery scientists want a breakdown of the total catch by species of, if that is not possible, by groups of closely related species. In the case of sorting by size groups, they require additional information on the quantities landed of each size group.

Fishermen are usually quite good in separating species, particularly in the case of species with a higher market value. In tropical fisheries it is often impossible to sort out the smaller fish, and in such cases samples need to be taken and analysed by a biologist to determine the species composition. The practical Species Identification Sheets have been developed for this purpose (Fischer, 1973 and 1978; Fischer and Whitehead, 1974).

For reporting statistical data, international classification of species and species groups have been prepared by international fisheries bodies. Classifications adopted for national purposes should be within the framework of the international agreed classification. Examples of up-to-date classifications of species and species groups for statistical purposes are given in FAO, 1974 and FAO/ICES/ICNAF/ICCAT/ICSEAF, 1974.

2.5 Fishing area and unit stock

Often a species of fish is distributed over a wide area of the sea where it may form only one stock or may be an aggregate of several independent unit stocks. Theoretically, a unit stock of a species is a population of fish that is essentially self-contained, occupies a particular area and lives independently of other similar populations. Fishing upon one unit stock should have no effect upon individuals of other stocks. Stock assessment techniques are most meaningful when they are applied

to unit stocks of a species. Biologists use methods based on counts of meristic characters, e.g. number of fin rays or vertebrae, physiological techniques (blood proteins) and tagging methods, for the delimitation of unit stocks. From a practical standpoint, statistical methods based on the spatial distribution of good catches can simplify the determination of the unit stock at least for immediate purposes. However, several unit stocks may mix in an area. If the pattern of fishing is relatively uniform over a wide area, the fish of a given species there may be treated as a single unit stock assuming that they do not differ greatly in reproduction, growth and mortality rates. On the other hand, if the intensity of fishing differs markedly within the area occupied by the species, and if fish from different parts of it rarely mix, the fish in each part may be treated as separate units of stock.

A first pre-requisite is therefore to know the area from which a species of fish is caught. If it is known that only one unit stock of a species is found in a particular area, then the area of capture identifies the unit stock fished. For example, all cod caught in the Barents Sea belong to the Arcto-Norwegian cod stock because that is the only cod stock which inhabits the Barents Sea as has been determined on the basis of biological studies.

One species may be landed from several different areas at one port. For example, cod are landed in Great Britain from every fishing area of the North Atlantic but the catches are taken from different unit stocks. The only way in which the effect of fishing can be related to each unit stock is to record the area from which the individual catch was taken. This may present few problems if the vessel has been fishing in one area only; but large freezer trawlers may be at sea for three months or more during which they may have fished several areas and therefore probably different units of stocks. In this case, it is usually only possible to get an estimate from the fishing skipper and his logbook of the quantity of fish taken and the effort exerted in any given area.

It is important to record fishing area in a standard way and FAO has proposed a set of major areas for statistical purposes (Table 2), and a set of statistical rectangles for this purpose (Figure 1A). FAO's system allows for the recording of catches by statistical squares as small as 10' latitude x 10' longitude, although this will rarely be possible. If data can be recorded in this manner the fishery can be examined in detail but utusally it is possible to get meaningful information for much larger areas only. It is important to make whatever statistical divisions that are used correspond to the realities of the fishery. Fishermen will give information by the names they give to their fishing areas. It is much easier to record this information if the statistical divisions correspond as closely as possible to the fishermen's areas. Also each division should correspond to the distribution, or partial distribution, of one fish stock. This is important when the fleets are highly mobile. At the other extreme will be the case where boats landing at a port are able to fish only one area, inhabited by only one stock of each species. In this case the port, or landing place, will be sufficient information.

The difficulties of combining data from several nations which have not used the same statistical breakdown of areas of fishing are obvious. At the minimum, the statistical squares used must correspond to the distribution of the stock, but a better understanding of a fishery can usually be obtained if smaller areas of fishing are used. Moreover, they must be standardized to be useful. Figure 2 shows an example of four nations each with its own divisions of a fishing area for one stock. The difficulties, say, of analyzing north-south movements from combined information are obvious. The example is hypothetical but it corresponds very closely to the situation for North Sea data on demersal species which existed before 1978. An example of good coordination is given in Figure 3.

2.6 Time of capture

It is necessary to know when the fish are captured, usually within a week or within a month. This information is used for analyzing seasonal abundance, migrations and in some cases obtaining growth data. Little difficulty is usually found in collecting date of capture with this precision, except for vessels which have been at sea for long periods. For these vessels it may be necessary to assume that the catch was all caught in a certain month, or to divide it arbitrarily between the months the vessel has been at sea, unless there is logbook information available.

2.7 Fishing effort and catch-per-unit-effort statistics (c.p.u.e.)

The concept of fishing effort varies with users. To an economist or technologist, the fishing effort means the amount of time, money, labour, technology and skill applied to catching fish, i.e. the work done or scarce resource used. To a fishery scientist, effort statistics provide a measure of the proportion of fish being caught, i.e. the relative abundance of the stock and of the fishing mortality. To the fishermen, the catch per boat or catch per landing is an index of performance.

The economist expresses the various inputs employed in catching fish in terms of money. The fishery scientist is not directly interested in the money value of the inputs. The simplest assumption he can make is that one unit of fishing effort (f) removes a constant proportion of the stock and is directly related to fishing mortality (F) by a constant q which is called the catchability coefficient, i.e. $F = qf$, or abundance = $^1/q$ (c.p.u.e.), where c.p.u.e. is the catch per unit effort. For example, if the fish in a pond are evenly distributed over the bottom, then one takes every fish in one quarter of the area, then one takes one quarter of the total stock regardless of whether there are 100 or 1 000 fish in the pond. The numbers taken by one unit of effort in this case, 25 or 250, are relative indices of abundance.

The theoretical concept that fishing effort is a measure of fishing mortality and c.p.u.e. is a measure of abundance cannot be directly used in many fishery situations for two reasons: (i) the catchability coefficient q is not constant because fish are not evenly or randomly distributed in most cases, and (ii) the difficulty in finding an index of fishing effort. In general, fishing effort is regarded as the product of fishing time and the fishing power of a vessel. In terms of a uniform density of fish, the fishing power of a vessel catching twice that of another vessel in the same area in one unit of time is taken as double that of the other.

The quantity of fish taken by a vessel per unit of time primarily depends on the size of the vessel, its horse-power and the type and size of gear used, but a large number of other factors such as age of the vessel, storage capacity, skill of the crew, technological aids available, etc. also play a large role (Brander, 1975). Based on these various factors, the FAO Fisheries Department (1973) has classified the fishing fleet into categories within which fishing power is less variable. Even this classification of fishing fleets into various fishing power categories does not solve our quest for a standard unit of fishing effort. For each fishing power category of vessels, an appropriate unit for the measurement of fishing time is needed. The criterion for choosing the unit measure of fishing time is that within the same fishing power, the catch is directly proportional to the number of time units elapsed.

While in the next section we shall discuss unit measures of fishing effort for some common fishing gears, it is worth mentioning that unlike catch statistics, there is no single standard unit of measurement for fishing effort statistics. There are series of units, each appropriate to a different method of fishing. Even for the same method of fishing there may be several ways of recording fishing effort.

2.8 Measures of fishing power and fishing time

The general recommendations of the FAO Fisheries Department on methods of recording fishing effort statistics are contained in Table 3(FAO, 1976a). The following discussions are in respect of specific fishing gears.

a) Bottom trawl

The fishing power of a bottom trawl depends on its size and the speed with which it is towed through water. The latter is usually closely related with the size and/or engine power of the vessel. Many studies have shown a linear relation between size or engine power of a vessel and its catch rate. Therefore, the collection of effort data by vessel size (gross tonnage of the vessel) or engine power category will eliminate the need for information on gear size and other characteristics correlated with size or power category.

There are several measures of time which may be used for each power category of trawlers. "Days absent from port" is the easiest to collect. This may be a good index if the fishing ground is close to the trawler's port, but if the fishing ground is a long way from the trawler's port, "days absent from port" will include the time spent in steaming to and from the ground as well as time spent fishing on the ground. The time spent on steaming to and from the fishing ground has nothing to do with catching fish. Furthermore, the measure "days absent from port" will not be comparable from year to year if the time spent on fishing changes over years. A better measure is "days on grounds" because it is more closely correlated to the amount of time actually spent on catching fish. But bad weather and breakdown may introduce bias in the time measure "days on grounds" because it will contain an element of time which is not spent in fishing. "Hours fishing" will be a more true measure for the time spent in searching for and catching fish, although in several bottom trawl fisheries, searching is of minor importance. Thus taking both fishing power (vessel displacement in tons) and fishing time (hours) into consideration, "ton-hours fishing" will probably be the best measure of fishing effort for bottom trawlers. Other measures referred to are ton-days absent from port, ton-days on grounds, etc. If information on "ton-hours fishing" are difficult to collect, other indices will also be useful (e.g. HP-days; the sum of the product of vessel horsepower and the number of days fished.)

b) Midwater trawl

In midwater trawling, engine power is the key factor determining the size of the net used and the speed of towing, and hence the fishing power of the vessel. Fishing effort data should therefore be collected by vessel engine power categories. Since in all midwater trawl fisheries searching (with echo-sounder or sonar) is an important component of fishing operations, the hours actually spent with gear deployed is an adequate measure of effort. Days fishing is likely to be a more satisfactory measure for midwater trawl fisheries, since it combines both searching and fishing time.

c) Purse seine

The size of the vessel (hold capacity) and its engine power may be equally important. The power of the engine may influence the speed and hence the success of a set within a vessel size category. Hence it may be necessary to combine both parameters in stratifying purse seiners according to their fishing powers.

As in the case of midwater trawls, searching is also an important part of fishing operations of purse seiners and vessels using other encircling nets. At the same time, since most encircling fisheries are based on small pelagic fishes and are susceptible to saturation of the handling and carrying capacity of the vessel, the unit of time chosen in calculating effort should be small enough to exclude this effect. Again, since vessels engaged in these fisheries take nearly the same time in shooting and hauling a net irrespective of catch, the best effort measure should include time spent in finding the shoal in the first place. Thus, the searching time is one of the best indices of fishing effort for purse-seiners and other vessels using encircling gears and fishing for small pelagic fish.

d) Gill net

The most important power factor is the size of the gear, which may be measured as the number or length of nets. Number of nets x days fished will probably give an appropriate measure of effort in most fisheries (ACMRR (FAO), 1976). However, it is necessary to remember that gear saturation effects occur in all gill and drift nets, and as such, the time such nets are in the water is not very important (Brander, 1975) and probably the number of nets alone may serve as a good measure of effort.

e) Hooks and lines (longlines, handlines, pole and line, troll, jigging)

The fishing power in hook-and-line fishing is mostly governed by the number of hooks operated during a fishing operation (sometimes measured in units of baskets or skates of line with a fixed number of hooks). As for the selection of the measure of time, the following considerations are important: (a) gear saturation effects are likely to occur in almost all kinds of line fishing, (b) in small-scale inshore line fisheries, fishing operations and trips are often of constant duration, (c) in tuna longling, soaking time remains more or less constant for each set.

Measurement of fishing time can thus be made by simply recording the number of sets, or in some cases the number of trips. Searching time is very important (in most surface tuna fisheries, e.g. pole and line) in pole and line fisheries, where trip duration has to be allocated to four components: steaming time between port and fishing grounds including other dead time, fishing for bait, searching time for schools, and catching time.

Based on the above considerations, the following measures of fishing effort are recommended (ACMRR (FAO), 1976):

Gear	Species	Measure of Effort
Handlines	Groundfish	Number of lines, soaking time (or trips)
Handlines on (electric) reels	Snappers, etc.	Number of reels x number of hours
Longlines	Groundfish, tuna	Number of hooks, number of sets
Troll lines	Tuna, salmon, pelagic	Time on fishing grounds, adjusted for number of lines
Jigging	Squid	Number of nights, adjusted for number of gear units
Pole and line	Tuna	Searching time and time on tuna fishing grounds, adjusted for number of hooks with, according to the particular fishery, additional adjustments for differences in bait, rigging, searching, number of gear units, etc.

f) Pots

Boat characteristics do not affect directly fishing power, but indirectly through the number of pots carried or set per trip (and possibly also on the presence or absence of a depth sounder for where suitable to bottom). Thus the main fishing power component in pot fisheries is the number of pots set and effort should be recorded accordingly, adjusting if gear saturation is a problem, by using trap days (number of traps x number of days fished).

g) Fixed traps

As in the case of pots, effort in this case is measured in terms of the number of traps-hauls (adjusted if necessary for soak time if this is not constant, or strictly additive in effect).

2.9 Total fishing effort

It has been mentioned that there is no single standard unit of measurement of fishing effort statistics. In fact, there are different units of measurement for different methods of fishing. Even for the same method of fishing, different fleets may have different fishing powers. Hence, in general, statistics of fishing effort are not additive, as is the case of catch statistics, and it often happens, both in the case of a national fishery as well as international fisheries, that different fleets use different gear to exploit a common resource. For the purpose of resource assessment, the fishery scientists would like to get a measure of the total effort that is being exerted on the common resources. In such cases, it is usual to express total fishing effort in terms of units of effort of one fleet of vessels chosen as a standard. For example, three fleets could be fishing the same stock and reporting the following statistics:

Fleet	Nominal catch (t)	Effort
x	7 500	Effort data not recorded
y	2 500	100 000 hours of trawling
z	10 000	500 days searching
TOTAL	20 000	

In the above example, fleet x does not have any record of effort statistics. Fleet y reports its effort in terms of hours of trawling and fleet z in units of days searching, and the total catch of the fleet is known. In this case, the total effort can either be expressed in the units of fleet y (i.e. hours of trawling) or in the units of fleet z (i.e. in days searching). When expressed in units of fleet y, the estimate of total effort is expressed as $\frac{20\ 000}{2\ 500} \times 100\ 000 = 800\ 000$ hours of trawling by fleet y, and when expressed in units of fleet z, the estimate is $\frac{20\ 000}{10\ 000} \times 500 = 1\ 000$ days of searching of fleet z. Now the question is which measure of effort is to be preferred? For the purpose of resource assessment, the following criteria for choosing the statistics for measure fishing effort should be kept in mind (Brander, 1975):

a) The selected unit of measure should relate to a fleet of single power category, i.e. the trawling hours of a fleet of one category should not be mixed up with the trawling hours of another power category.

b) The unit of measure should preferably relate to that fleet category which is more widespread, and has better coverage in area and time, i.e. the fleet which fishes the stock over a wider area for a longer period.

c) The chosen unit of measure should be persistent, i.e. it should preferably relate to a fleet which has undergone little or no technological changes, so that a long time series of comparable statistics of fishing effort are available.

In many fisheries only the effort of a small group of vessels within a particular vessel category, or for one vessel category out of many landings is known. An example is a coastal shrimp fishery where small shrimp trawlers as well as local canoes exploit the same stock. Estimates of catch are obtained by sample survey methods for each category of fleet but estimates of effort only for the trawlers. The total effort is estimated by raising the partial effort figure of trawlers by a raising factor equivalent to the total catch divided by the catch of trawlers. The total effort in this case is measured in units of trawlers' effort. When applying such a method of estimating, it should be borne in mind that the reliability of such estimates depends heavily on how closely the catch per unit effort of the whole fleet resembles that of the known part. In cases where the fleet as a whole is very heterogeneous, but there is a single group of reliable vessels of the same category, the only possible method of deriving the total effort is from the data of the catch per effort of this vessel category, providing the estimate of the total catch from all vessels is available.

3. Planning of a catch-effort survey

There are a number of questions that require consideration in the planning of a survey and a catch-effort survey is no exception in this regard. The questions needing consideration may conveniently be discussed under the following broad classifications:

a) Objectives: specification of the purpose of the survey

b) Coverage: definition of the population, categories of material to be covered

c) Types of information to be collected: degree of subdivisions of data; and method of measurements

d) Method of collection of data

e) Choice of frame or construction of a frame if none is available

f) Choice of sampling unit and type of sample, whether stratified, multistage, etc., determination of size of sample and method of selection

These questions cannot be considered in isolation of one another. In fact, they are interdependent. For example, there is usually a fixed budget allotted for a catch-effort survey and this will definitely influence the coverage of the survey, degree of subdivisions of catch and effort statistics to be collected, size of sample and hence the accuracy of the survey results. If in the construction of a frame, enumeration of minor fishing units, i.e. fishermen using small gear without a vessel for nearshore coastal fishing is excluded, the coverage of the catch-effort survey will have to exclude the minor fisheries also. The choice of sampling method to be adopted will again depend on the availability of the type of frame.

A fairly good knowledge of the fishery and fishing practices prevailing in a country is necessary in arriving at correct decisions on many of the above questions. It is highly desirable to have some advance knowledge on the types of fishing units in operation and if they vary in size and fishing power, their season of operation, the area where they fish, the general magnitude and variability of the catch and species composition of the catch, etc. Knowledge is also required in the landing practices, i.e. where the landings take place, when they occur, if they take place at any particular time of the day or are spread over the whole day, or if different units land at different times of the day, etc. If prior knowledge in these matters is not easily available, a pilot or exploratory survey is essential as many of the decisions on various questions of a catch-effort survey will depend on some knowledge of these. The following sections briefly deal with the broad group of questions on which decisions are needed at the planning stage of a catch-effort survey.

3.1 Objectives

The purpose of collecting catch and effort statistics has been stated in Section 1. They are necessary, and are needed by a variety of users such as planners, economists, fishery scientists, fishermen, etc. Sub-divisions of these statistics into various categories have also been discussed in Section 2. The degree of sub-division of the catch and effort data statistics by species, area, time, fishing gear and vessel category, etc. will, however, depend on the requirements and the uses to which these data will be put.

In some countries, for example, if there is only an inshore artisanal fishery, with no plans for development of the fishery except for some marginal or cosmetic improvements, there are no compelling reasons why detailed statistics with finer sub-divisions are necessary. In such cases, perhaps a simple estimate of catch by broad species groups together with an estimate of number of canoes or even number of active fishermen as measure of effort will be sufficient. Again there are countries where commercial fisheries are being developed or have been developed side by side with artisanal fisheries. While for artisanal fisheries, statistics of catch by broad species with some simple measures of effort will meet the requirements, for industrial fisheries there may be need for early management measures and consequently detailed statistics of catch and effort are needed in order to arrive at reasonable decisions regarding the permissible quantity of catch, number of vessels, processing facilities, etc. to avoid the risk of over-inestment. In developed countries, bigger vessels of various types are employed for fishing and they fish over a wide area of the sea, and land at fixed harbours at regular intervals. In such cases, detailed sub-divisions of catch and effort by species, area, time, and fishing gear within various vessel categories will be required.

Hence, very careful consideration is necessary at the planning stage to clearly specify the type of information it is proposed to collect and also the degree of sub-division of this information. The more detailed the requirements of the data, the higher will be the cost of collections and it is always necessary to strike a balance between requirements and cost.

3.2 Coverage

It is necessary to specify the coverage of the survey, i.e. the types of material it is going to cover and its geographical scope. The geographical scope of a survey can easily be described, e.g. the survey of catch-effort statistics of Lake Volta, the marine fish catch and effort statistics of Somalia, etc. but sometimes it is necessary to be more specific to define the geographical scope. For example, it may be specified that marine catch-effort statistics will not include fishing activities in estuaries, backwaters and lagoons. As regards coverage of materials to be surveyed, it is first necessary to define the "population" of survey units. Whenever a survey is contemplated concerning any field of activities, it is necessary to divide the survey materials into small physical units which can be observed or measured for the desired characteristics. In a fishery, fish are caught by operating various types of gear from a boat or sometimes even without a boat. A major fishing unit consists of boat, gear and crew, while a minor fishing unit is composed of fishing gear and fishermen. In a catch-effort survey the fishing units (both major and minor) are the survey units and the quantity of catch by species caught by them is the characteristic which is observed or measured. Another characteristic is the fishing effort of these fishing units, a description of how it is to be measured and in what units for different fishing units has been given in Section 2.8. It may be noted that all survey units are not similar. They may range from a hand-operated cast net through a small canoe with a drift net or hooks and line to a big trawler or purse seiner or a tuna longliner. In specifying the coverage, it should be stated explicitly which are the survey units that are going to be covered and which are the ones that are not going to be covered in the survey. If it is decided not to cover the minor fishing units, the estimate of catch derived from the survey will not include the catch obtained by the minor fishing units.

Sometimes the objectives of a survey may be confined to getting catch and effort statistics in respect of a particular type of fishery within a country, e.g. the trawl fisheries of Thailand, the shrimp fisheries of India, or say the gill net fisheries of Lake Volta. In these cases, the coverage will include only those fishing units engaged in the fisheries concerned. Thus in the Thai trawl fisheries, the survey units will be the trawlers engaged in demersal fishing, and in the case of the Indian shrimp fisheries the survey units will be the shrimp trawlers as well as the canoes engaged in shrimping. The survey units of Lake Volta gill net fisheries will be the boats operating gill nets.

3.3 Type of information

It has already been emphasized in Section 3.1 that the type of information and degree of sub-divisions of the catch and effort statistics depend very much on the type of fisheries that are being surveyed. In artisanal fisheries, landings by species will generally correspond to catch by species. In the case of those fisheries where a sizable quantity of fish is discarded at sea, information on the quantity and size composition of the discards may be necessary in addition to quantity of landings by species.

For measure of effort also, it will be necessary to decide what statistics need to be collected and these will again depend on the type of fisheries. The measures of effort statistics and their units for various types of fishing units have already been discussed.

What is essential in the planning stage is to decide precisely on the items of information to be collected and to devise appropriate proforma for collecting them. The practicability of collecting certain information (e.g. quantity of discards by species, and their size composition) has also to be considered at this stage. If it is felt that collection of such data may be difficult in a general survey of catch and effort, a special sample survey may be designed to collect such data and obtain their estimates.

3.4 Method of measurement

The landings of a fishing unit surveyed must be sorted out by species or species groups (if it has not already been done) and their weight taken and recorded. The data on fishing effort is obtained by enquiry, and expressed in units appropriate to the fishing unit.

There are, however, some practical problems, especially with regard to taking weights of landings by species. It is pertinent to mention them, and suggest ways of handling them. In developed countries, catches are generally sorted out by species or by commercial varieties, put in standard boxes or containers, and landed. In such cases, there are no difficulties in taking the weights of landings by species. The weights recorded can also be verified from sales notes which are invariably prepared by all fishing companies for each vessel on the day of landing, providing the catch and value of each commercial variety of fish landed. But in small-scale fisheries of developing countries, the landing practices are not similar. The landings of hooks and line and drift net fisheries, usually consist of large size fish which are landed and then sorted out by commercial category. It is not always possible to measure the weight of each and every individual fish. The usual practice is to count the number of fish of each variety which is rather easy, and multiply it by the corresponding average weight obtained by weighing a few specimens chosen at random in order to get the weight of landings by variety. In seine fisheries, a large quantity of assorted small fish is caught and they are sometimes arranged in standard baskets and landed. It is usual practice to record landings in the field in such cases in units of baskets, and later convert them to wet landings using conversion factors which are usually prepared at the planning stage, or before the implementation of the survey, or sometimes even on the day of observation. The size of the baskets may vary from place to place or there may be several sizes in the same place, and in such cases care is necessary to mention the basket size at the time of recording. The species composition is either obtained by eye-estimate, or by a special survey undertaken by biologists, if necessary.

Sometimes a huge quantity of assorted small pelagic fish is caught and landed in heaps, and either spread on the beach for drying, or dumped into waiting vehicles to be carried away. In such cases, only eye estimates are possible. When this practice is very common there are needs for calibration experiments for enumerators in adjusting the eye estimates.

3.5 Method of collection of data

There are basically two methods by which statistics of catch and effort are collected, viz. (1) the complete enumeration or census methods, and (2) the sample survey method or sometimes a mixture of the above two methods.

3.5.1 Complete enumeration methods

Complete enumeration methods are usually employed in fisheries of developed countries where fishing is carried out by large fishing vessels which discharge their landings at a small number of fishing ports or harbours. The statistics of catch and effort are collected from each and every vessel, either by log-book method or by direct observation at the fishing ports.

a) Log-book method

In this method, log-books or log-sheets are designed to provide required information on catch by species or varieties, gear used, area of fishing, time of leaving and returning to the port and appropriate measures of effort corresponding to the type of fishing. Usually the log-sheets are designed to allow different fishing units to be specified, as measures of effort are in different units for different gear. Appropriate log-sheets are then distributed to the skippers of each fishing vessel who fill them up using separate sheets for separate trips. These sheets are then either mailed by the skippers to a central office (usually the Department of Fisheries) or are collected at the fishing ports by the agents of the central office. The compilation and tabulation is done at the central office.

The advantage of this method lies in its simplicity. The final processing of the data merely consists of tabulation and compilation of the information contained in the filled up log-sheets received from the vessels. But in practice, there are drawbacks. First, the response is not complete if the system of skippers mailing the log-sheets is adopted. Often the skippers forget to send them and if they are not taken from the vessels in time, they are taken back to sea and lost. Second, the information recorded by the skippers may not always be accurate. Fishing skippers are often too busy on board the vessels to fill up the logs at the completion of each fishing operation, and much of the contents of the log sheets are written from memory much later. Species identification is often very poor and this introduces error in the weight of species caught. Sometimes the area of fishing is not correctly recorded as a matter of policy. Some of these problems may be resolved to some extent by someone familiar with the fishery, others by treating the portion of vessels completing logs as a sample fleet; others are basically unsolvable and introduce an inevitable element of bias into the estimates.

b) Direct observation method

As a variation of the log-book system, the other complete enumeration method is the system whereby the landings of each and every vessel at each port is directly observed and data collected and recorded by enumerators in forms similar to log sheets. This eliminates response error, and ensures correct recording of weights of landings by species and also details of fishing gear used to catch the fish. The skipper or crew of the vessels are interviewed for data on areas fished, and on the time spent fishing, searching, etc. Any other information such as data on discards are also obtained by enquiry. The value of the fish landed is obtained by attending the sales, which are by open auction.

If a vessel fishes in more than one area, the breakdown of the catch and species taken in each area is usually very approximate as the information given are from memory of the skipper and crew. The same remarks apply in respect of time spent in each area.

3.5.2 Sample survey method

In most developing countries, fishing activities are confined to the small-scale or traditional sector, where fishing is carried out by a large number of small boats of various sorts using many types of gear and the catches are landed at numerous sites scattered along the coastline or along the shorelines of lakes and rivers. Complete enumeration of such landings is physically and financially infeasible. Reliable estimates are possible only through sample surveys. Even industrial fisheries in some of these countries are based on numerous medium-sized modern vessels, and a sample survey alone is the only feasible method to obtain estimates of catch derived from them along with estimates of effort input. In sample survey methods, data on catch and effort from a sample of survey units selected according to established procedures are collected by direct observations, and based on these data, estimates of catch and effort are obtained.

3.6 Frame

It has been stated in Section 3.2, that in a catch-effort survey, fishing units are the survey units and the quantity of fish by species caught by them, and the amount of effort expended by them, constitute the survey characteristics that are measured. Before a sample for catch-effort survey can be drawn, the units in the surveyed population must be defined and presented in some ordered form. Any such ordered presentation is called a sampling frame. In a catch-effort survey, usually the landing sites are the primary sampling units and fishing units at each landing site are the second stage sampling units.

A sampling frame is generally obtained from a frame survey which is a sort of inventory survey to collect information on the basic characteristics of the fishing industry. Usually, information is collected on the following basic items during a frame survey:

a) Number and area distribution of fishing villages and fish landing sites

b) the number of boats or fishing units, and

c) the number of fishermen

Other additional information such as the following are also collected during the frame survey:

a) the nature of the landing sites (i.e. if they are permanent or seasonal)

b) the landing practices (i.e. if the landings take place at certain hours or are spread throughout the day and night)

c) the composition of the boats or fishing units (by types and size)

d) fishing grounds exploited by different fishing units (inshore, offshore or deep sea etc.)

e) the disposition of the catch

If the above auxiliary information is available, along with the list of sampling units, they can be used in planning more efficient sampling designs and also in making more efficient methods of estimating catch and effort.

For the field operation of the frame survey, there are essentially two approaches, viz. (1) ground survey approach, and (2) aerial survey approach. Sometimes, a combination of the above two approaches is used.

In the "ground survey" method, the survey area is first divided into a number of convenient geographical strata and within each stratum the field survey involves (i) moving along every mile of the coast or shore line, (ii) identifying all fishing sites and fish landing sites, (iii) enumerating different types of fishing units at each site by physical counting as well as by interviewing fishermen and (iv) collecting other auxiliary information by enquiry. As the ground survey approach involves physically moving along the entire coast or shoreline and collecting information by visiting each identified fishing site, it is possible to collect all the desired information planned in the frame survey and the chances of coverage error are less. But this method is time consuming and sometimes may be very difficult to carry out in cases of extensive coast lines with well-spread artisanal fisheries, and of some inland fisheries of big lakes and river basins spread over difficult terrains. In such cases, the aerial survey approach is the alternative.

In an aerial survey, the field operations consist of (a) viewing from an aircraft moving over the coast/shore of the water area under survey, (b) detecting all fishing sites/fish landing sites along the coast/shore, (c) plotting their location in existing topographical maps and giving a serial number for identification, and (d) obtaining estimates of the size of each fishing site/landing site in terms of number of "boats seen". The method quickly provides an area frame of the landing sites along with estimates of their sizes in terms of boats seen at each site. It also provides information on the relative importance of the various regions in terms of regional concentration of fishing boats. The area frame can be used in planning a further survey using ground survey approach. It can also be used for selection of samples for other surveys such as catch-effort survey.

Bazigos (1974, 1978) describes these two methods with reference to obtaining a sampling frame for catch-effort survey of both inland and marine waters and Banerji (1974) describes two approaches to ground survey methods with reference to catch-effort survey of marine fisheries in West Africa. For further details see the above references.

3.7 Sampling design

Fish landings take place all round the year at the landing sites scattered along the coastline of a country or around the shoreline of an inland water mass (e.g. lake, river etc.). The catch-effort survey is, thus, a survey in both space and time and the sampling method to be adopted for a survey involves "sampling in space and time".

We have stated before that in a catch-effort survey, the primary sampling units are the fish landing sites. Thus, sampling in space involves the selection of a sample of fish landing sites from the population of fish landing sites. It has been found from experience that a more precise estimate of catch and effort is obtained if the survey area is first stratified into several geographical strata, each stratum containing a number of landing sites and selection of landing sites are made from each stratum, than if the selection of landing sites was made directly from the unstratified survey area. Several types of information may be used for effective stratification. The waters around the coastline of a country (or the waters along the shoreline of a lake or river) may not be equally productive. The abundance and the species composition may vary from one part to another and these may influence the landings of fishing units discharging at landing sites in the various regions. If we have precise information on the distribution and abundance of resources in the waters around the survey area or, alternatively, if we have some prior information (e.g. from a pilot survey) on the magnitude and composition of catch per fishing unit in the different landing centres, we can use them to divide the survey area into several more or less homogeneous strata. Sometimes other types of information may be available for use in such stratification. For example, the type of fishing units or boats in use may vary from one region to another; the use of different types may have been prompted either by the necessity of exploiting the resources available in the adjacent waters or may have been developed to face the prevailing oceanographical conditions of the fishing area or may have been evolved through local traditions or availability of materials for constructing them. Since the catch is greatly influenced by the type of fishing units employed, the information on their use and distribution, if it is available, may also be used in stratifying the survey area.

Next comes the problem of selection of sample landing sites within each stratum. The alternatives are: either a simple random selection of landing sites or selecting the landing sites with probability proportional to the number of boats at each site (pps).[1/] The latter method of selection is possible only if the number of boats at each landing site is known. If simple random selection is used, it is to be considered if further stratification of the landing sites within a stratum will increase the gains from stratification. For various reasons, fish landings per boat at larger landing sites are found to be higher than at small landing sites. Thus further stratification of the landing sites according to sizes is advisable before simple random selection of landing sites is made.

At each landing site, several types of fishing units may land their catch. Since the quantity and the composition of the catch vary from type to type, it may be necessary to collect data for them separately. This is stratification of the second stage units. Then, there is the question of the method of selection of the fishing units of different types at each selected landing site. They may either be selected at random from among existing fishing units at the landing site before the landings start or they may be selected at the time of landings either at random or systematically with a random start. In the former method of selection, a prior listing of all fishing units by types at the selected landing centre is necessary. If the fishing units do not always land at the landing sites to which they belong, it may be difficult to observe the catch of those selected units which land at a site different from the selected one. If such practice is common, it is preferable to use the second method of selection.

It is well known that there are seasonal variations in the abundance and composition of the fishery resources and these are reflected in the catches landed in different seasons. Thus in a catch-effort survey, it is necessary to have some sort of time stratification. These time strata should be neither too short nor too long but should be of such duration that within each time period the abundance and composition of fishery resources being exploited remain more or less unchanged. In most cases, stratification by months serves the purpose. The next problem is to decide the length of the survey period at each selected landing site, and how to select them. Usually, the length of the survey period at a selected landing site depends on the variations of day to day catches at the site, and how to select them. Usually, the length of the survey period at a selected landing site depends on the variations of day to day catches at the site and it has been found that in most cases the optimum survey period is about 3 to 4 days' duration. The method of selection of the survey periods is done either at random or a systematic selection is made with a random start. Then, within a month period, the selected landing sites are randomly allocated to the selected survey periods.

The selected landing sites within a geographical stratum may be kept fixed over the monthly strata or they may be selected afresh every month. From the point of view of sampling theory, it is highly desirable to have rotation of sample both in the primary and secondary stage of selection. But this

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1/ Probability proportional size

may introduce many practical difficulties. If the landing sites are selected afresh every month, the field enumerators will be in new and unfamiliar environments every month and apart from personal inconveniences they may not readily get the needed cooperation of fishermen in collecting data. The cost of travelling may also increase. For these reasons, it is often decided to keep the selected landing sites fixed over months. This sampling method is also useful for calculating estimates of changes that are taking place over time. For the second stage units, rotation is automatically ensured if the fishing units are selected systematically at the time of landings.

The method of estimation of stratum catch and effort will depend on the method of selection of the landing sites as well as the fishing units within a landing site and it is very necessary that an appropriate method of estimation is applied (Appendix I).

Some case studies of catch-effort surveys are given in the following section.

4. Case studies

In this section, two case studies are presented. The first relates to the catch-effort survey in Lake Tanganyika, which is an inland water mass. The second case study refers to the catch-effort survey of marine fish landings in Mauritius. For plans of fishery surveys in use in other countries, reference may be made to Chakraborty (1976), Banerji (1973, 1974) and Yamamoto (1973).

4.1 Lake Tanganyika fisheries surveys (Tanzania)

The fisheries are artisanal and are carried out by numerous fishing boats using various types of gear and operating from numerous fish landing sites scattered along the shoreline. A catch-effort survey carried out by sample survey method was designed by the Lake Tanganyika Fisheries Project, and is described by Bazigos (1973). The primary objective of the survey is to obtain reliable current estimates on a regional basis, for the Tanzanian part of Lake Tanganyika, of the total quantity of fish harvested by the fishermen at the lake (in terms of live weight in metric tons). Secondary objectives include the species composition of the catch and the fishing effort involved in obtaining the catch.

The sampling method used for the survey can be described as sampling in space and time.

Using available limnological information and data concerning the area distribution of the fishing sites, the lake is first divided into seven areas or strata. In order to obtain possible gains from stratification, each stratum is further divided into a number of area zones or minor-strata by taking into account the level of localization of the fishing industry.

From each minor stratum, two PSUs are selected with probability proportional to the number of fishing boats. For the purpose of this survey, the selected sample of PSUs is kept fixed over time. Table 4 shows the selected sample of PSU's. The PSU's are selected with pps, since the number of boats in each PSU is known from the available sampling frame.

The Fishing Economic Units (FEUs) are taken as the survey units. An FEU is defined as an integral unit composed of fishing boat, fishing gear and fishermen to carry out fishing operations. The selection of samples of FEUs within the sample fishing sites is made systematically with a random starting point. The time strata are lunar months, i.e. the survey is designed to provide estimates of catch and effort by lunar months. Within each lunar month, the selected PSU's (fixed sample of fishing sites) are randomly allocated in survey periods (in this case a four-day period). The first day of the survey period is used to prepare a list of existing FEUs within the sample fishing site. Items of information of catch and effort are collected in the remaining three days.

For the field operation of the survey, seven working groups (WGs) are available. Each WG consists of a statistical recorder and an assistant. One WG is assigned to each stratum. For the transportation of the WGs between selected fishing sites two boats are used.

For the collection of the information at the selected fishing sites, four forms are used; Forms: BO, B1, A1 and A2 (pages 30 to 33). The form BO is used to list the existing FEUs at the sample fishing sites and collect items of information on the components of the FEUs. This form is also used for the classification of the existing FEUs into groups according to the fishing method used. Form B1 is used to select samples of active FEUs at the sample fishing sites. Samples of FEUs are selected in each survey day separately for each fishing method.

Form A1 is used to collect items of information of fishing effort and fish catch from the selected catch from the selected landings using lusenga, lift nets or beach seines for dagaa as a fishing method. Form A2 is used for collecting similar information on fishing effort and catch from selected landings from gill net, beach seines for fish, and handlines.

The tabulation is done in two stages. In the first stage, the processing is done manually to obtain estimates of total catch. For this purpose, Work Sheets WS 01 and WS 02 are designed with detailed instructions on how to use them. The second stage involves mechanical processing of the sample data for the preparation of the detailed tables of the survey providing estimates of fish catch on a species basis and fishing effort involved.

4.2 Marine fisheries survey in Mauritius

The marine fishery activities in Mauritius may be conveniently divided into the following categories, viz:

a) The inshore fishery in the lagoon within the coral reef and the offshore fishery beyond the reef (lagoon fishery).

b) The fisheries on St. Brandon, Nazareth, Saya de Malha and other Banks (bank fisheries).

c) Distant-water tuna fisheries by foreign vessels with a base in Mauritius.

The catch-effort survey in Mauritius is chosen as a case study, since this country has an artisanal fishery in the lagoons, semi-industrial fishing in the banks, and an industrial fishery for tuna; and the survey methods for each of these fisheries are different.

4.2.1 Lagoon fishery

The coastline of Mauritius is about 225 km. A depth of 100 fathoms is reached within a few km of the fringing coral reefs. Fishing in the lagoons is carried out with large seine nets, canard nets in conjunction with seine nets, gill nets, traps and lines. Basket traps and lines are also used outside the reef within 10 fathoms and lines only within 100 fathoms contour. Lagoon fishery is more productive along the east coast. On the west coast, the Black River region is rich followed by Baie du Cap in the southern sector. There are 62 landing sites. In 13 out of these 62 landing sites, the Fisheries Protection Service has control posts for checking illegal fishing practices but it also estimates the fish landings at these 13 and 12 other neighbouring landing sites. These estimates are based on overall examination of the landings and general enquiries made at the landing sites and are not reliable. Besides, no estimates of landings are available for the other landing centres. Hence, an objective sample survey for the catch-effort survey of the lagoon fisheries was planned and implemented by the Fisheries Research Service from 1976. The basic features of the sample-survey method employed is described below. For details, reference may be made to Banerji (1976).

The landing sites are first divided into two main strata, the first stratum containing 25 landing sites for which the Fisheries Protection Service estimates are available and the second stratum containing the other landing sites. Based on available information of productivity of the different areas of the lagoon, the landing sites in major strata are further stratified according to their distribution in three coastal areas into which the coastline is divided.

In each minor stratum, a sample of two landing sites are selected. For minor-strata of stratum 1, the selection is made with probability proportional to the average landings at each site as obtained from the Fishery Protection Service estimates. For the minor-strata of stratum 2, the selection is made with probability proportional to the number of registered fishermen at each site.

The time strata are months. Within each month, 2 weeks are selected at random and randomly allocated to two selected landing sites at each minor-stratum. The survey period at each landing site is thus a week from Monday through Saturday. Since landings in each site are spread over 24 hours, a day is divided into 3 time strata, viz. morning (6 to 12 hours), afternoon (12 to 18 hours), and night (18 to 6 hours).

The selection of landing sites in each minor stratum as per scheme of selection mentioned above is made in the office of the Fisheries Research Service. Each minor-stratum is allotted to one field enumerator, and he collects data at each of the selected landing sites during the selected week allotted to each site. Statistics of all boat landings are collected on Mondays in the afternoon, on Tuesdays in the morning, and the data for the night between Mondays and Tuesdays are also collected by enquiry on Tuesday morning. The process is repeated for the subsequent days of the week. At the end of the month,

field enumerators send the data for concerned minor-strata to the office of the Fisheries Research Service for processing. Form 1 is designed for collecting data of landings at selected landing sites. Working Sheets 1A and 1B are designed to obtain monthly estimates of catch by variety and effort for each minor-stratum with the help of small desk calculators.

4.2.2 Bank fisheries

The bank fisheries operation are currently carried out by private companies using refrigerated vessels which are used as motherships and transporters of fish caught in the banks. The motherships carry pirogues and fishermen from Mauritius and proceed to the banks where fishing is done by hand-lining from pirogues. The fish caught in the banks are transported by the refrigerated vessels and landed at Port Louis in Mauritius.

Data on catch and effort are collected by census method from all refrigerated vessels. Simple forms (Form 2A) are provided to skippers of refrigerated vessels which they are required to fill up for every fishing trip. The information required consists of total catch and the number of days fished by banks fished. The unit of effort is taken as a fisherman-day, since each fisherman uses a standard handline with fixed number of hooks.

The variety composition of the catch is obtained by sampling the landings. A fisheries assistant is present at the port at the time of landing of a refrigerated vessel, the time of arrival of which is notified in advance, and he takes a sample of 3 to 4 boxes out of the total landings, sorts them out by variety and measures their weights and records these data in Form 2B. These sample weights are then raised to obtain estimates of variety composition of the total landings (column 3 of Form B2).

4.2.3 Tuna fisheries

There is a tuna fishing base in Port Louis at which foreign tuna vessels discharge their catch. The tuna is bought by a Japanese company based there and transshipped to other countries. The company buys fish landed by vessels from different countries, e.g. Japan, Korea, Panama. According to the agreement between the Government of Mauritius and the company, the company is required to furnish data of tuna landings of foreign vessels at Mauritius. The Fisheries Research Service collects the data from the company.

The skippers of the tuna vessels record the details of catch in log books maintained by them. The log sheets provide information on catch by varieties for each haul and the area of the hauls. Copies of these log sheets are furnished to the company by the skippers of vessels selling their catch. As vessels of different countries use log sheets prescribed by their respective countries, these log sheets are not uniform. The Japanese vessels provide information of fishing time in each area of fishing, others only give the total number of fishing days without breakdown by area although catches by area are recorded. In addition to the data provided by the log books, the company at the time of purchase of fish, weighs the fish bought and maintains sales record giving weights of fish by varieties.

The Fisheries Research Service of Mauritius obtains from the company a monthly statement in a prescribed form (Form 3) which for each vessel landed provides data on effort and catch by variety.

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Table 1. Standard definitions of basic terms

(Source: FAO, 1976)

Term	Definition	Synonyms	Weight Basis
Landings	The weight of fish and fish products brought ashore, i.e. the actual weight of the quantities landed. This weight represents the net weight of the gutted, eviscerated, filleted, frozen, cured, canned fish and fish products, fish meals, oils, etc. at the time of landing	Landed weight	Landed weight
Nominal catch	The live weight equivalent of the landings	Landings, round fresh Landings, whole fresh Landings, ex-water weight	Live weight
Catch	The term "catch", unless otherwise specified, normally refers to the "nominal catch", i.e. the live weight equivalent of the landings	Landings, round fresh Landings, whole fresh Landings, ex-water weight	Live weight
Gross catch	The total weight of all fish and other aquatic animals and plants taken from the water consisting of the "retained catch" and the "discarded catch"	Real catch	Live weight
Discarded catch	That part of the gross catch which, as whole fish, is returned to the sea at the time of capture	Discards	Live weight
Retained catch	That part of the gross catch which, as whole fish, in various processed forms is retained on board	...	Live weight

Footnote to Table 1.

The difference between "retained catch" and "landings" is due to:

a) consumption by the crew

b) use for bait

c) dumping of whole fish because of spoilage or for other reasons

d) dumping of guts, heads and other parts of the fish because of processing

e) loss or gain of fluid content

The difference between "retained catch" and "nominal catch" is accounted for by items (a), (b) and (c) above.

The difference between "nominal catch" and "landings" is accounted for by items (d) and (e) above.

The term "landings" is not used in international statistics synonymously with "number of arrivals" or "trips".

Data on "gross catch", "discarded catch" and "retained catch" will generally be available only in logbook entries reflecting estimates by skippers or other crew members of the quantities involved; these estimates might vary from the results ("nominal catch") obtained by converting recorded landings to their live weight equivalent.

Table 2 Major fishing areas for statistical purposes (from FAO, 1973b)

	INLAND WATERS
01	Africa
02	America, North and Central
03	America, South
04	Asia
05	Europe
06	Oceania
07	USSR
(08)	(Antarctica)

	MARINE AREAS
	Atlantic Ocean and adjacent seas
18	Arctic Sea
21	Atlantic, Northwest
27	Atlantic, Northeast
31	Atlantic, Western Central
34	Atlantic, Eastern Central
37	Mediterranean and Black Sea
41	Atlantic, Southwest
47	Atlantic, Southeast
48	Atlantic, Antarctic
	Indian Ocean and adjacent seas
51	Indian Ocean, Western
57	Indian Ocean, Eastern
58	Indian Ocean, Antarctic
	Pacific Ocean and adjacent seas
61	Pacific, Northwest
67	Pacific, Northeast
71	Pacific, Western Central
77	Pacific, Eastern Central
81	Pacific, Southwest
87	Pacific, Southeast
88	Pacific, Antarctic

NOTES ON FISHING EFFORT STATISTICS

This appendix is taken from FAO Fisheries Circular No. 429. It describes methods of recording fishing effort statistics as recommended by FAO.

1. Fishing Time

(a) No. of hours or 1000 hooks fished

No. of hours fished: for otter trawls this is defined as "the total number of hours during which the trawl was on the bottom and fishing"; if countries are unable to report so precisely they should give the nearest approximation with the precise definition of the approximation used.

No. of hours fished: for dory vessels this is defined as "the number of hours the dory fleet is absent from the mother vessel times the number of dories".

Thousands of hooks fished: this is defined as "the number of hooks used in each set times the number of sets". This figure should be calculated to the nearest thousand hooks.

For other fishing gear: the number of hours the nets, seines, traps, pots, dredges, harpoons etc. were used in the fishing operations; this is the product of the number of hours per unit times the number of units.

(b) No. of hauls, drags or sets made

The number of times the fishing gear has been hauled or dragged or set, whichever description is appropriate to the fishing gear or technique used.

(c) No. of days fished

The number of days (24-hour periods, reckoned from midnight to midnight) on which any fishing took place.

For those fisheries in which searching is a substantial part of the fishing operation, days "on grounds" in which searching but not fishing took place, should be included in the days fished data.

Taking into account the inclusion of "searching time" the definition of "number of days fished" could be further refined at the national level if possible as follows: "The number of days (24-hour periods, reckoned from midnight to midnight) on which the fishing craft was on the fishing grounds, intent on catching fish (not counting the time spent steaming to or from port and between grounds) minus the number of fishing days lost through delays from weather, breakdown or other factors".

(d) No. of days on grounds

This is defined as the number of days (24-hour periods, reckoned from midnight to midnight) in which the craft was on the fishing ground, and includes in addition to the days fishing and searching also all the other days while the craft was on the ground.

(e) No. of days absent from port

The number of days absent from port on any one trip should include the day the fishing craft sailed but not the day of landing.

Where it is known that fishing took place on each day of the trip the number of "days absent from port" should include not only the day of departure but also the day of arrival back in port.

Where on any trip a fishing craft visits more than one "fishing area" (as defined for statistical purposes) an appropriate fraction of the total number of days absent from port should be allocated to each "fishing area" in proportion to the number of days spent in each, so that the total number of days absent on any trip will be the sum of the number of days allocated to all of the different "fishing areas" visited.

(f) No. of trips made

Any voyage during which fishing took place in only one "fishing area" is to be counted as one trip.

When in a single trip a craft visits more than one "fishing area" an appropriate fraction of the trip should be apportioned to each "fishing area" in proportion to the number of days spent fishing in each, so that the total number of trips for the Statistical Area as a whole will be the same as the sum of trips to each "fishing area".

2. Fishing Power

(a) Average gross tonnage

Average gross tonnage is to be given in gross registered tons.

The averages should be weighted. Weighted averages are required in view of the decision to reduce the reporting task of the national offices by eliminating for the time being the monthly breakdown of the annual effort measure data.

(b) Average horse-power

Data should be given in "brake horse-power". For steam engines give the data instead as "indicated HP".

The HP averages should be given as straight i.e. unweighted averages, or as weighted averages, with an indication of the type of average used. Weighting is to be calculated on the basis of "number of trips".

(c) Average length, overall

The overall length should be given; if this is not possible and if the registered length is substituted the word "overall" in this line is to be deleted and "reg" inserted. The length data should be given in metres (1 British foot = 0.3048 m).

These length averages should be given either as straight (unweighted) averages or as weighted averages with an indication of the type of average used. Weighting is to be calculated on the basis of "number of trips".

(d) No. of fishing units operating

The number of fishing units operating should inlcude every unit within the relevant "class of fishing units" that fished at least once in the fishing area.

In the case of "pair boat" fisheries the two craft together comprise one fishing unit.

3. General Remarks on Priority in Providing Data on Fishing Effort

For detailed standard definitions of the various types of effort see sections 1 and 2 of Part D.

Countries are asked to indicate in separate memoranda the extent to which the effort data provided on the reporting forms comply or deviate from these detailed standard definitions.

According to the priorities indicated below in sections 3.3 and 3.4 national reporting offices are requested to provide the data relating to the appropriate types of fishing effort.

In giving data on fishing time effort measures, the following desirable priorities are to be followed:

First priority: either "no. of hours fished" or "1000 hooks fished" should be provided; in addition, "no. of hauls, drags or sets made" should also be given.

Second priority: "no. of days on ground" and "no. of days absent from port".

Third priority: "no. of trips made".

In giving data on fishing power effort measures, the following desirable priorities are to be followed:

First priority: "average gross tonnage" (see section 2.1)

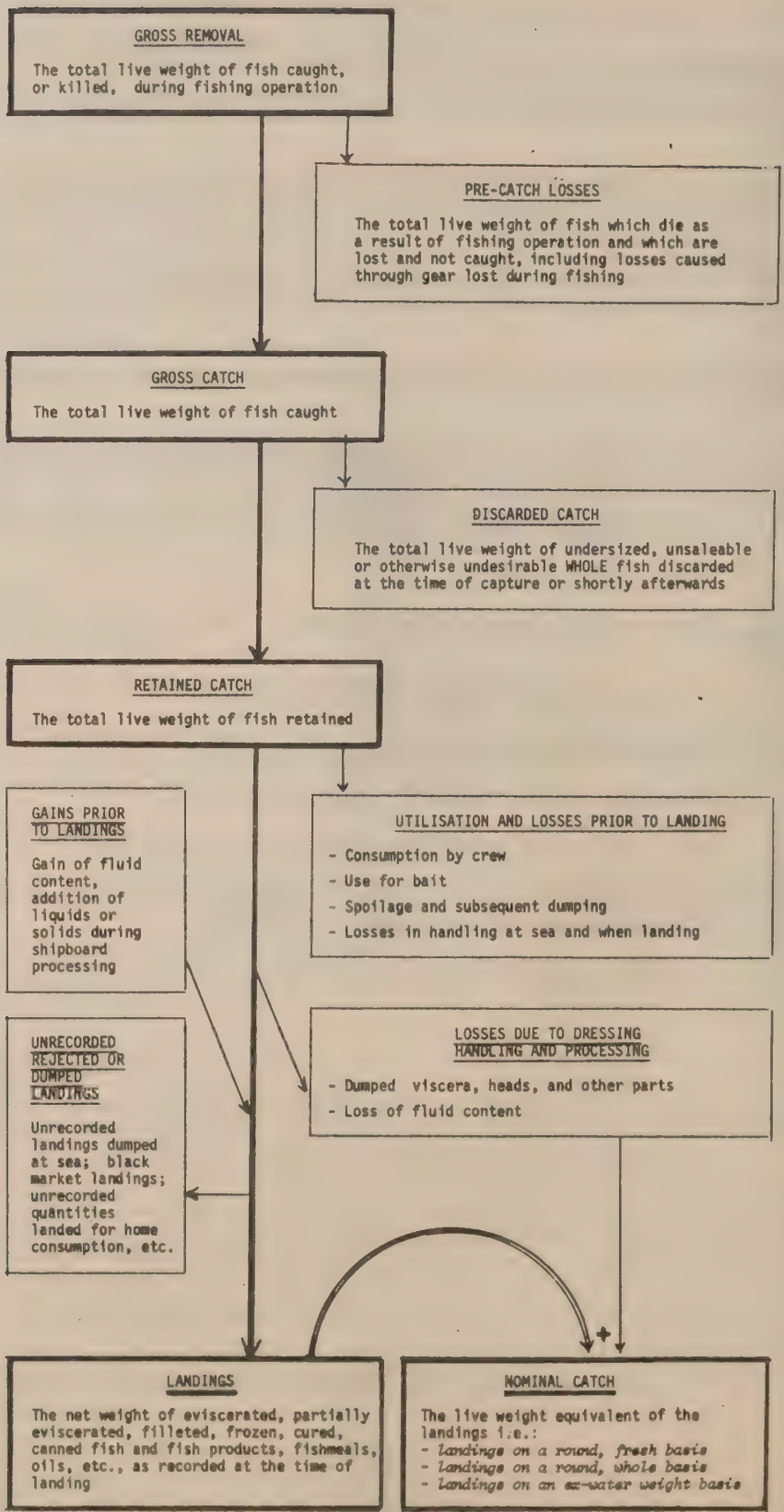
Second priority: "average horse-power" (see section 2.2)

Third priority: "average length, overall" (see section 2.3)

Fourth priority: "no. of fishing units operating" (see section 2.4)

In addititon, national offices are also to indicate the extent to which effort data provided were not recorded but were obtained by sampling.

Figure 1


GROSS REMOVAL
The total live weight of fish caught, or killed, during fishing operation
PRE-CATCH LOSSES
The total live weight of fish which die as a result of fishing operation and which are lost and not caught, including losses caused through gear lost during fishing
GROSS CATCH
The total live weight of fish caught
DISCARDED CATCH
The total live weight of undersized, unsaleable or otherwise undesirable WHOLE fish discarded at the time of capture or shortly afterwards
RETAINED CATCH
The total live weight of fish retained
GAINS PRIOR TO LANDINGS
Gain of fluid content, addition of liquids or solids during shipboard processing
UTILISATION AND LOSSES PRIOR TO LANDING
- Consumption by crew
- Use for bait
- Spoilage and subsequent dumping
- Losses in handling at sea and when landing
UNRECORDED REJECTED OR DUMPED LANDINGS
Unrecorded landings dumped at sea; black market landings; unrecorded quantities landed for home consumption, etc.
LOSSES DUE TO DRESSING HANDLING AND PROCESSING
- Dumped viscera, heads, and other parts
- Loss of fluid content
LANDINGS
The net weight of eviscerated, partially eviscerated, filleted, frozen, cured, canned fish and fish products, fishmeals, oils, etc., as recorded at the time of landing
NOMINAL CATCH
The live weight equivalent of the landings i.e.:
- landings on a round, fresh basis
- landings on a round, whole basis
- landings on an ex-water weight basis

CODE TO INDICATE SIZE OF RECTANGLE

Code	Latitude		Longitude
1	10'	x	10'
2	20'	x	20'
3	30'	x	30'
4	30'	x	1^{o}
5	1^{o}	x	1^{o}
6	5^{o}	x	5^{o}
7	10^{o}	x	10^{o}
8	20^{o}	x	20^{o}
9	30^{o}	x	30^{o}

CODE TO INDICATE QUADRANT

Code	Quadrant of Globe	
1	NE	Northeast
2	SE	Southeast
3	SW	Southwest
4	NW	Northwest

Size Quadrant

x x

xx^{o} xx' xxx^{o} xx'

Latitude Longitude

Fig. 1A A graticule system (based on latitudes and longitudes) for identifying statistical rectangles (from FAO 1973b)

Figure 2 Example of different division-breakdowns of the same subarea by four nations

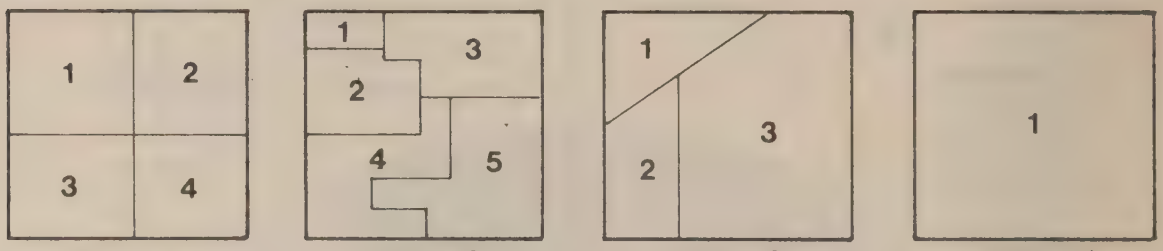


Figure 3 Example of different divisions for two tuna species of Atlantic Ocean

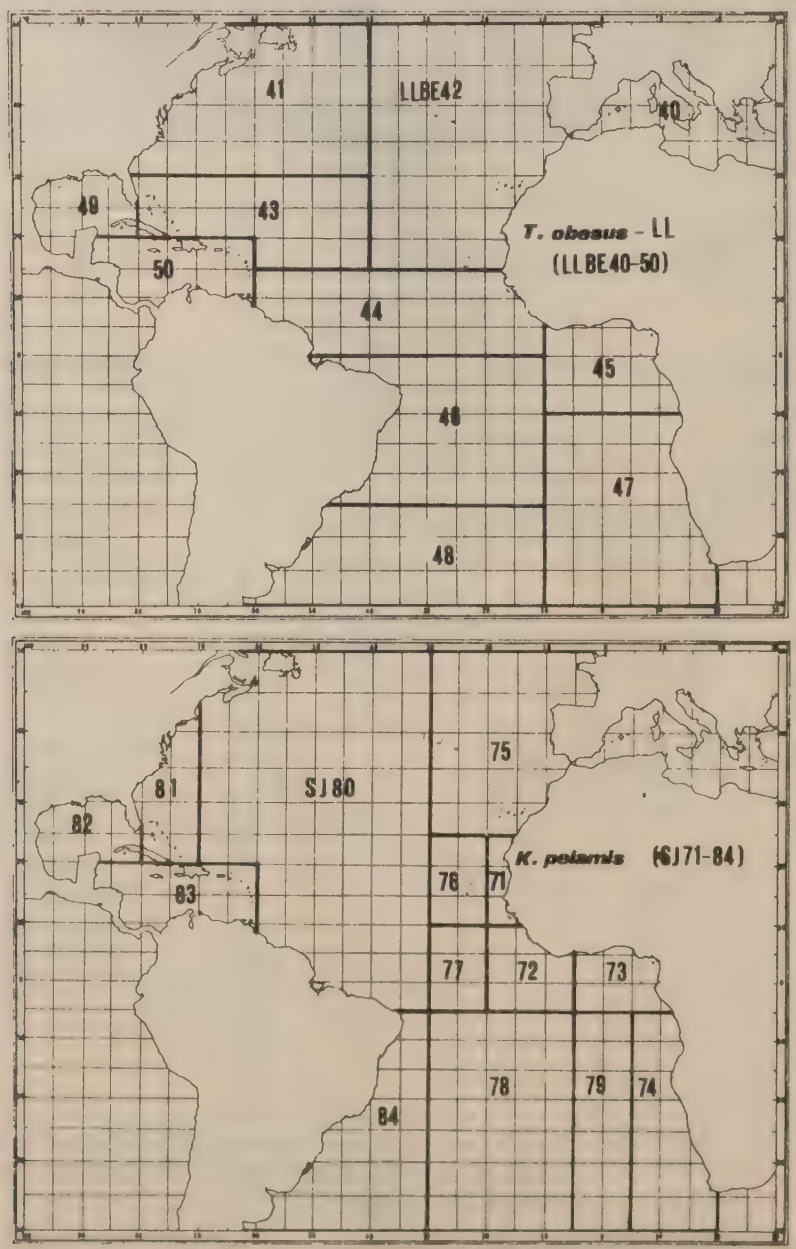


Table 4 Selected sample of PSU's

Stratum : 1 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
111	Makombe	
112	Ngonya	
	Mtambala (R)	(Reserved)
121	Makasa	
122	Kitwe	
	Bugamba (R)	(Reserved)
131	Ngeru	
132	Kalalangobo	
	Kogongo (R)	(Reserved)
141	Katonga	
142	Kasaba	
	Kampande (R)	(Reserved)
151	Mwakizega	
152	Kasigo	
	Mchangani (R)	(Reserved)

Sizes:		
	M-Str:11	690c
	M-Str:12	599c
	M-Str:13	584c
	M-Str:14	439c
	M-Str:15	493c
	Total	2805c

Stratum : 2 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
211	Kite	
212	Kirando	
	Lugufa (R)	(Reserved)
221	Ngangasima	
222	Kangweno-II	
	Mkuyu (R)	(Reserved)
231	Helembe	
232	Mgondozi Camp-II	
	Kashe (R)	(Reserved)

Sizes:		
	M-Str:21	629c
	M-Str:22	587c
	M-Str:23	721c
	Total	1937c

Stratum : 3 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
311	Makola	
312	Lufubu	
	Kalya (R)	(Reserved)

Sizes: M-Str:31 258c

Stratum : 4 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
411	Ikola	
412	Karema	
	Kasanga (R)	(Reserved)

Sizes: M-Str:41 140c

Stratum : 5 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
511	Mkombe-I	
512	Kambwe-I	
	Katoba (R)	(Reserved)
521	Shashete-I	
522	Chongo	
	Katete (R)	(Reserved)
531	Kipili	
532	Uwile (ISL)	
	Mtakuja (R)	(Reserved)

Sizes: M-Str:51 252c
M-Str:52 360c
M-Str:53 393c

Total 1005c

Stratum : 6 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
611	Katale	
612	Chombo	
	Kisambala-I (R)	(Reserved)
621	Msamba	
626	Wampembe	
	Kizumbi (R)	(Reserved)

Sizes: M-Str:61 227c
M-Str:62 349c

Total 576c

Stratum : 7 - Selected fishing sites/CAS

C.No.	Name	Location (see map)
711	Chowe	
712	Kilambo	
	Tundu (R)	(Reserved)
721	Kipanga	
722	Kasanga	
	Musi (R)	(Reserved)

Sizes: M-Str:71 308c
M-Str:72 367c

Total 675c

Estimated size of the fishing industry by Minor-stratum
(Frame Survey - Jun/Jul 1973, map-data)

Stratum	Min-str	Number of fishing boats	Remarks
		Total 7396	
Str:1		2805	
	1.1	690	
	1.2	599	
	1.3	584	
	1.4	439	
	1.5	493	
Str:2		1937	
	2.1	629	
	2.2	587	
	2.3	721	
Str:3		258	
	3.1	258	
Str:4		140	
	4.1	140	
Str:5		1005	
	5.1	252	
	5.2	360	
	5.3	393	
Str:6		576	
	6.1	227	
	6.2	349	
Str:7		675	
	7.1	308	
	7.2	367	

LAKE TANGANYIKA FISHERIES RESEARCH AND
DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)

FORM: B1 (1.1)

SELECTION OF FEU'S

Name of the Recorder _____ ☐

Landing date ☐☐☐

Sample fishing site: C.No ☐ Name _____

Primary Fishing Method: C. No.	LUSENGA (1)		GILLNET (2)		BEACH-DAGAA (3)		BEACH-FISH (4)		LIFTNET (5)		HANDLINES (6)		Remarks
1. No. of existing FEU's													
2. No. of inactive FEU's													
3.(1-2) No.of active FEU's													
	Ser.No.		Ser.No.		Ser.No.		Ser.No.		Ser.No.		Ser.No.		
	Pop. (1)	Sam. (2)	Pop. (1)	Sam (2)	Pop. (1)	Sam. (2)	Pop. (1)	Sam (2)	Pop. (1)	Sam. (2)	Pop. (1)	Sam. (2)	

APPENDIX IIIb - FORMS USED FOR THE CATCH ASSESSMENT SURVEY (CAS)

LAKE TANGANYIKA FISHERIES RESEARCH AND DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)

FORM: Bo(1.0)

Page____

LIST OF EXISTING FISHING ECONOMIC UNITS

Name of the Recorder _____ ☐

Survey date ☐☐☐

Sample fishing site

C.No. ☐

Name _____

FEU's (1)	FISHING METHOD		FISHING BOAT		CREW					Remarks (11)
	Prim (2)	Other (3)	Type (4)	Reg. No. (5)	Total (6)	Boat owner (7)	Crew leader (8)	Assis-tants (9)	Other (specify) (10)	

LAKE TANGANYIKA FISHERIES RESEARCH AND DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)

FORM: A1 (1.2)

CATCH RECORDS
(LUSENGA, BEACH DAGAA, LIFTNETS: 1, 3, 5)

Name of the Recorder _____ ☐ Selected FEU:C.No. ☐☐☐

Landing date ☐☐☐☐☐☐ Name of fishing site _____

1.Particulars of fishing unit	(ASK): Complete the following table:											Remarks
	A.Fishing boat		B.Crew					C.Gear				
								Nets		Other		
	Reg.No. (1)	Type (2)	Total (3)	Boat owner (4)	Crew leader (5)	Asst (6)	Other (spec) (7)	Kind (8)	No. (9)	Kind (10)	No. (11)	(12)

2.Fishing operation	(ASK): Time: 1. Started: 2. Completed: 3. Number of hauls: 4. Did your boat pick up other boat(s) catches? Yes ☐ 1 No ☐ 2

3. Fish Catch							4. Fish Sold			Remarks
		Boxes		Baskets			Quantity			
Species (1)	Weight kgs. (2)	Size (3)	No. (4)	Size (5)	No. (6)	No. of fish (7)	Unit of measure. (8)	No.of units (9)	Shs/ Unit (10)	(11)
01.0 Dagaa										
02.0 Mikebuka (Luciolates)										
03.0 Lates										
99.9 Other fish										

Sizes of boxes/or baskets: 1 = small size
2 = medium size
3 = large size

LAKE TANGANYIKA FISHERIES RESEARCH AND DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)

FORM: A2(1.3)

CATCH RECORDS
OTHER FISHING METHODS

Name of the Recorder _____ ☐ Selected FEU:C.No. ☐☐☐

Landing date ☐☐☐ Name of fishing site _____

1.Particulars of fishing unit	(ASK): Complete the following table:							Remarks (8)
	A. Fishing boat		B. Crew					
	Reg. No. (1)	Kind (2)	Total (3)	Boat owner (4)	Crew leader (5)	Assistants (6)	Other (spec.) (7)	

2.Fishing operation	(ASK): Time: 1. Started: 2. Completed: 3. Number of hauls (for beach-fish): 4. Did your boat pick up other boat(s) catches? Yes ☐ 1 No ☐ 2

3.Number of fishing gear used	2. Gillnet		4.Beach-fish		6.Handlines		7.Other (specify)	Remarks
	1.Mesh size		Mesh size	No.	No.HL	No.Ho.		
	2.No.of nets							

4. Fish catch								5. Fish sold			Remarks (12)
Species		Weight kgs.	Boxes		Baskets		Number of fish	Quantity		Shs/ Unit	
C.No. (1)	Name (2)	(3)	Size (4)	No. (5)	Size (6)	No. (7)	(8)	Unit of measure. (9)	No.of units (10)	(11)	

Sizes of boxes/or baskets: 1 = small size 2 = medium size 3 = large size

LAKE TANGANYIKA FISHERIES RESEARCH AND DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)
a.Round: ____
b.Minor Stratum: ____

WORKING SHEET 01 (WS:01)
(EXISTING FEU's AND THEIR COMPONENTS)

Selected fish.site/ fish.meth. (1)	RF $\left(\frac{1}{P_i}\right)$ (2)	f_i D_i (3)	No.of existing FEU's (4)	Components of the existing FEU's (5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1 ☐☐		T_1												
		D_1												
2 ☐☐		T_2												
		D_2												
3		$\bar{D}$												
1 ☐☐		T_1												
		D_1												
2 ☐☐		T_2												
		D_2												
3		$\bar{D}$												
1 ☐☐		T_1												
		D_1												
2 ☐☐		T_2												
		D_2												
3		$\bar{D}$												

LAKE TANGANYIKA FISHERIES RESEARCH AND DEVELOPMENT PROJECT (TANZANIA)
CATCH ASSESSMENT SURVEY (CAS)

a.Round:

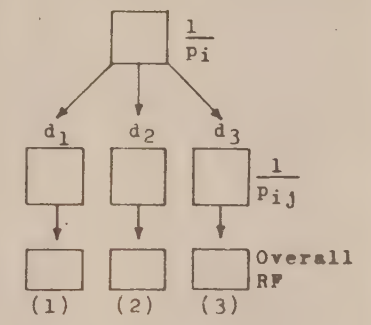
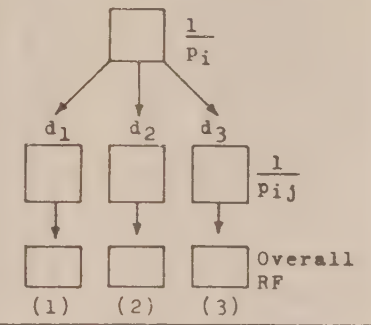
b.Minor Stratum:

c.Fishing method:

d.Characteristic(s):

e.Unit(s) of measurement:

WORKING SHEET 02 (WS:02)
(FISHING EFFORT, FISH CATCH)

Selected fishing site/fishing method (1)	Selected fishermen (2)	Sample day:d_1 (3)	(4)	Sample day:d_2 (5)	(6)	Sample day:d_3 (7)	(8)	$d=d_1+d_2+d_3$ (9)	(10)	RAISING FACTORS (11)
	01									
	02									
	03									
	04									
☐☐	05									
	06									
	07									
	08									
	09									
	10									
	T_1									
	D_1									
	01									
	02									
	03									
	04									
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	06									
	07									
	08									
	09									
	10									
	T_2									
	D_2									

Note:

$T_{1,\ 2}$: Sample total of a given variate (sample day basis)

$D_{1,\ 2}$: $T_{1,\ 2}$ x Overall Raising Factor (sample day basis)

f: | |

g: | |

$\frac{D_1+D_2}{2} = \hat{D}$

$\hat{T} = c \times \hat{D}$

c = Time Raising Factor

PROCESSING

INSTRUCTIONS FOR THE COMPLETION OF WS:01

1. The purpose of WS:01

WS:01 is used to calculate estimates (totals) of the existing Fishing Economic Units and their components within the established minor strata and within the fishing methods used. Estimates are calculated on a lunar month basis. Annual estimates are obtained by adding up the monthly estimates.

2. The format of WS:01

WS:01 consists of two parts, the heading of the sheet and the body of the sheet.

3. The heading of WS:01

Insert:

a) The number indicating the round of the survey: R:01, stands for the first lunar month; R:02, stands for the second lunar month, etc.

b) The code number (two digits) of the minor stratum you are dealing with e.g. 11 or 31, etc.

4. The body of WS:01

Within each minor stratum two fishing sites have been selected. Further, for each sample fishing site, Form:Bo has been completed. In the form items of information are collected on the number of existing FEU's, the fishing method(s) used by the units and their components.

4a. Recording the items of information

The body of the sheet is divided into three sections (each section consists of three parts, 1, 2, 3). A section is used to calculate estimates of the survey characteristics on a fishing method (primary fishing method) basis within the given minor stratum. The input data of the sheet are given in the completed Form:Bo.

In each section of the body of WS:01 items of information are recorded on a sample fishing site basis. Specifically, line $1.T_1$ is used to record the <u>total value</u> of a given characteristic in the first selected fishing site and within the given fishing method e.g. in Col:4 you should insert the total number of FEU's using Lusenga as primary fishing method. Line $2.T_2$ is used to record the total value of the same given characteristic in the second selected fishing site and within the same given fishing method. In lines $1.D_1$ and $2.D_2$ the sample totals are infered to the minor stratum totals. Specifically, to get the values in line $1.D_1$ one must multiply the recorded values in $1.T_1$ by the respective raising factor (Col:2). Also, to get the values in line $2.D_2$ one must multiply the recorded values in $2.T_2$ by the respective raising factor (Col.2). The estimated value of each survey characteristic is obtained in line 3D:

$$3\hat{D} = \frac{1}{2}(1.D_1+2.D_2)$$

4b. The raising factor, RF

The RF in a given part of a section is calculated by the formula:

$$RF = \frac{\text{Total number of existing FEU's in the minor stratum}}{\text{Total number of existing FEU's in the selected fishing site}}$$

Note that data on the total number of existing FEU's (fishing boats) on a minor stratum basis are given in section 3.2 of the report. Col:4 of the sheet is used to calculate estimates of the total number of existing FEU's by fishing method used. Cols:5-15 are used to calculate estimates of the various components of the FEU's. For each characteristic one column should be used. In the headings of the columns insert the names of the survey characteristics.

PROCESSING

INSTRUCTIONS FOR THE COMPLETION OF WS:02

1. The purpose of WS:02	WS:02 is used to calculate estimates (totals) of the dynamic characteristics of the CAS i.e. fishing effort, fish catch, etc. within the established minor strata and within the fishing methods used. Estimates are calculated on a lunar month basis. Annual estimates are obtained by adding up the monthly estimates.
2. The format of WS:02	WS:02 consists of two parts, the heading of the sheet and the body of the sheet.
3. The heading of WS:02	Insert: a) The number indicating the round of the survey: R:01, stands for the first lunar month; R:02, stands for the second lunar month, etc. b) The code number of the minor stratum you start calculations. c) The name of the fishing method and its code number e.g. LUSENGA, 1. d) The name of the characteristic(s) under estimation. e) The unit(s) of measurement of the survey characteristic(s).
4. The body of WS:02	Within each minor stratum two fishing sites have been selected. Further, in each sample fishing site and within the fishing methods used, items of information are collected from the sample FEU's for three consecutive days (completed questionnaires, Form:A1 or A2). The body of WS:02 is used to receive the items of information from the completed forms A1 or A2 and infer them to the minor stratum totals.
4a. Recording the items of information	The body of WS:02 is divided into two identical sections in their structure. The first section is used to receive the items of information from the first selected fishing site and the other section to receive the data from the second selected fishing site. Within each section one line is allocated to record the data per selected FEU, (completed Form:A1 or A2). As you know, an independent sample of FEU's have been selected within each sample day (there are three sample days within each lunar month/fishing site). Therefore, within each section of the body of WS:02 items of information must be recorded on a sample day basis. The columns of the body of WS:02 Col: 1, 2, stand for the sample code numbers of the selected FEU (see Form: A1 or A2). Specifically; in the large box insert the code number of the selected fishing site, in the small box insert the code number of the fishing method. In Col:3 the serial numbers of the selected FEU's are presented (there is room to insert up to 10 FEU's). Col: 3, 5, 7, are used to record the values of the characteristic under estimation of the selected FEU's in sample day-1, sample day-2 and sample day-3 respectively. Col: 4, 6, 8, are spare columns to be used for recording the values of a second characteristic.
4b. Calculation of the overall raising factors, RF	Calculations of the overall raising factors must be made on a sample day basis and within each section of the body of WS:02. Col: 11: In this column there is a pyramid of boxes in which you have to insert certain arithmetical values i.e.:

a) In the box on the top of the pyramid ($\frac{1}{p_i}$) you have to write a fraction with the enumerator indicating the total number of FEU's in the minor stratum (see section 17.3.2) and the denominator indicating the total number of the existing FEU's in the selected fishing site (see Form:Bo).

b) The three boxes in the middle of the pyramid stand for the three sample days d_1, d_2, d_3. For a given sample day you have to insert in the proper box a fraction, the enumerator indicating the total number of active FEU's within the given fishing method and the denominator indicating the number of selected FEU's (see Form:B1).

c) The three boxes at the bottom of the pyramid are used to estimate the overall raising factors RF within the three sample days {(1), (2), (3)}. The estimation of the values of RF is a mechanical operation i.e. the value of the overall raising factor of the first sample day is given by: "fraction in box d_1" × "fraction in top box"; the overall raising factor of the second sample day is given by: "fraction in box d_2" × "fraction in top box", the overall raising factor of the third sample day is given by: "fraction in box d_3" × "fraction in top box".

4c. Calculation of estimated totals

For the calculation of the estimated totals the following procedure must be used:

1. In each section of the body of the WS:02 and within the respective sample days total the sample values of the survey characteristic. The calculated values must be recorded on the lines with indications T_1 and T_2.

2. Multiply the calculated values (sample totals) with the respective overall raising factors RF, and insert the obtained products on the lines with indications D_1 and D_2.

3. Add horizontally the calculated products of the three days and insert the obtained totals in column 9 or 10 respectively (remember: Col: 3, 5, 7, 9, are reserved for one characteristic and Col: 4, 6, 8, 10, for another characteristic).

4. Calculate vertically the average D_1 and D_2 totals ($\frac{D_1+D_2}{2}$) within Col: 9, 10, and insert the estimated average totals in the boxes with indication f.

5. Multiply the estimated average totals by the respective Time Raising Factor c, and insert the obtained results in the respective boxes with indication g. The obtained magnitudes are the calculated monthly total estimates (lunar month) of the survey characteristics.

Note:

$$c = \frac{\text{Total number of days in a lunar month}}{\text{Number of sample days } (=3)}$$

Form 1. Record of Fish Landings at Selected Centres

Stratum :
Name of Selected Centre :
Name of Enumerator :

Date of Observation :
Period of Observation : Morning/Afternoon :

Col. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Serial No. of landings	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	Night landings (by enquiry)
Reg. No. of boat																	No. of boats landed:
Gear Used																	
No. of Fishermen																	No. of fishermen involved:
Varieties						Weight in Kg											Approximate varietywise landings in kg
33. Grouper																	
Sea basses																	
Sea breams																	
Goat and Parrot fish																	
Lethrinidae																	
Other percoids																	
34. Mullets																	
Caranx																	
Other carangids																	
35. Sardines																	
Anchovies																	
36. Mackerel																	
Skipjack																	
Yellowfin																	
Other tunas																	
38. Sharks																	
Skates and rays																	
39. Miscellaneous																	
43. Lobster																	
Prawns																	
53. Octopus																	
Oyster																	
Total																	

Working Sheet 1A. Estimated Monthly Landings at Selected Centres

Stratum:
Selected Centre:

Month and Year:

(Fill up from columns 16 and 17 of Form 1)

Col. No.	1	2	3	4	5	6	7	8	9	10	11	12
Sample day										Sample Total for 3 (d) days	Estimated monthly total	$\hat{Z}_i = \frac{\hat{Y}_i}{\overline{W}_i}$
Period	A	N	M	A	N	M	A	N	M	col. 1-9	$\hat{Y}_i$ = col. 10 x $\frac{D}{\overline{d}}$	col. 11 x $\frac{1}{\overline{W}_i}$
No. of Landings												
No. of Fishermen												
Varieties					Weight in Kg							
Groupers												
Sea basses												
Sea breams												
Goat and Parrot fish												
Lethrinidae												
Other percoids												
Mullets												
Caranx												
Other Carangids												
Sardines												
Anchovies												
Mackerel												
Skipjack												
Yellowfin												
Other tunas												
Sharks												
Skates and Rays												
Miscellaneous												
Lobster												
Prawns												
Octopus												
Oyster												
Total												

Working Sheet 1B. Estimated Monthly Stratum Landings
(use separate sheet for each stratum)

Stratum: Month and Year:

Col.No.	1	2	3	4	5	6	7	8	9	10	11
Selected Stations										$\sum Z_i$ = sum of columns 1-9	Estimated Monthly Stratum Total = col. 10x$\frac{W}{n}$
		Values of Z_i from col. 12 of Working Sheet 1A									
No. of Landings											
No. of Fishermen										10	
Varieties				Landings in kg (Z_i)							
Groupers											
Sea basses											
Sea breams											
Goat and Parrot fish											
Lethrinidae											
Other percoids											
Mullets											
Caranx											
Other carangids											
Sardines											
Anchovies											
Mackerel											
Skipjack											
Yellowfin											
Other tunas											
Sharks											
Skates and Rays											
Miscellaneous											
Lobster											
Prawns											
Octopus											
Oyster											
Total (Z_i)										$\sum Z_i$ =	$\hat{Y}$ =
Z_i^2										$\sum Z_i^2$ =	

$$\bar{Z} = \frac{1}{n} \sum Z_i$$

$$V(\hat{Y}) = \frac{W^2}{n-1} \left\{ \sum Z_i^2 - n\bar{Z}^2 \right\}$$

=

=

Form 2A Record of Bank Fisheries Operations

Part I (either to be filled by the company or by the fishery staff on the day of landings)

1. Name of Company:
2. Name of Mother Vessel:
3. Name of Pirogues small:
   large:
4. Number of Fishermen:
5. Year:
6. Trip number in the year
7. Trip starts on:
   and ends on:

Name of Banks		Number of Fishing Days	Total Catch in kg	Remarks (weather condition etc.)
(1)		(2)	(3)	
St. Brandon				
Nazareth				
Saya de Malha				
Others (specify)				
Total			(W)	

Form 2B Record of Bank Fisheries Operations

Part II (To be worked out by fishery staff). Variety composition.
(Take a sample of 3 to 4 boxes out of the total landings and work out the variety).

Composition

Sample		Estimated weight of total landings $W_i = w_i \times \frac{W}{w}$
Varieties	Weight (w_i)	col.2 x $\frac{W}{w}$
(1)	(2)	(3)
Total	(w)	

W= weight of total landings

FORM 3. Monthly Returns of Tuna Landings in Mauritius

Longline Fisheries | Month and Year: | Name of Company:

Flag Country and Name of Vessels	Effort		Catch in tons according to varieties														
	No. of Fishing Days	No. of hooks (in 1000)	Bluefin	Albacore	Big Eye	Yellowfin	Skipjack	Other Tunas	Blue Marlin	Black Marlin	Striped Marlin	Spearfish	Sailfish	Swordfish	Sharks etc.	Others	Total
Korea																	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
Subtotal																	
Japan																	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
Subtotal																	
Panama																	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
Subtotal																	
Taiwan																	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
Subtotal																	
Total																	

APPENDIX I BASIC SAMPLING THEORY AND SAMPLING DESIGN

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APPENDIX II TABLE OF RANDOM NUMBERS

APPENDIX I

BASIC SAMPLING THEORY AND SAMPLING DESIGNS

1. Population, Frame, Sampling Units, Survey Units

Whenever a survey is contemplated, it is first necessary to define the materials to be covered by the survey. For this purpose, it is necessary to divide the survey materials into small physical units called survey units which can be easily identified and which can be measured or observed for a desired character or characters. In a fishery, fish is caught by operating a gear from a boat or sometimes only with a gear. A gear operated from a boat is a major fishing unit and a gear operating by itself is a minor fishing unit. Thus in a catch survey a fishing unit constitutes the survey unit whose catch is measured. It is needless to say that survey units need not be similar. In a fishery, the survey units may range from a unit of small cast net to a big trawler.

In a complete enumeration or census, the desired characteristics of all survey units are measured. In a complete enumeration or census survey, it is not always necessary to have a prior list of survey units, it is enough if the survey unit is defined and enumerators list all units at the time of survey and also measure the desired characteristics. In a sample survey on the other hand, since we select a sample, there must be a prior list of sampling units from which the sample is selected. A sampling unit could be a survey unit itself or it may be a group of survey units. Thus in a sample survey for catch, the sampling units could be the fishing units or they could be the landing sites where a group of fishing units discharge catch.

A list of sampling units is called a "frame" or a "list" and the aggregate of sampling units is called the population of sampling units to be surveyed. When the sampling units are different from survey units, the selection of a sample is made from sampling units but characteristics are still measured on the survey units. Thus we may select a sample of landing sites but measure the catch of fishing units landing in the selected landing sites.

2. Method of Selection

In a sample survey, we deal with random selection of a sample as against purposive or judgement selection. In random selection, every sampling unit of the population has a known probability of being selected in the sample.

Simple Random Sample (SRS)

If there are N units in the population and we want to draw a sample of n units, there are $N_{C_n} = \frac{N!}{n!(N-n)!}$ possible samples when sampling without replacement. If the procedures of selection is such that each of these possible samples has an equal chance or probability of selection, then the type of sampling is called simple random sampling (SRS) and the particular sample chosen is a simple random sample.

Now let us take an example. Assume there are N = 6 landing sites in the population designated as 1_1, 1_2, 1_3, 1_4, 1_5 and 1_6 and we want to select a sample of n = 2 landing sites. There are $6_{C_2} = \frac{6!}{2!\,4!}$ 1/ = 15 possible samples of two landing sites. They are:

$(1_1\ 1_2)$, $(1_1\ 1_3)$, $(1_1\ 1_4)$, $(1_1\ 1_5)$, $(1_1\ 1_6)$
$(1_2\ 1_3)$, $(1_2\ 1_4)$, $(1_2\ 1_5)$, $(1_2\ 1_6)$, $(1_3\ 1_4)$
$(1_3\ 1_5)$, $(1_3\ 1_6)$, $(1_4\ 1_5)$, $(1_4\ 1_6)$, $(1_5\ 1_6)$

1/ $6! = 1 \times 2 \times 3 \times 4 \times 5 \times 6$

In practice, when N is large, it is not possible to enumerate all possible distinct samples and then select one of them. Normally, a simple random sample is drawn unit by unit. The units in the population are marked serially from 1 to N. Then we refer to a table of random numbers (Appendix II) and draw from this table a series of n numbers lying between 1 and N, taking care to reject numbers above N and not allowing the same numbers to appear in the series more than once. The units in the population marked as per the number selected in the series constitute our sample of n landing sites. It has been proved that this method produces simple random samples.

Example

There are N = 28 landing sites in a district. We want a simple random sample of n = 5 landing sites.

Since N = 28 is a two-digit number, we refer to any row of two-digit numbers in the Random Number Table. Referring to the first row of two-digit numbers, we find the consecutive numbers are: 23, 5, 14, 38, 97, 11, 43, 93, 49, 36, 7, etc.

Now select those that lie between 1 and 28, until we have selected a series of 5 numbers. The selected series is: 23, 5, 14, 11 and 7.

The landing sites marked with these numbers in the population constitute our sample.

3. Estimation of population mean from a sample and precision of estimate

If there are N units in the population and we measure a desired characteristic (y) of all units in the population, then we have:

$$\text{Population Total} \quad : \quad Y = \sum_{1}^{N} y_i = y_1 + y_2 + y_3 + \ldots + Y_N$$

$$\text{Population Mean} \quad : \quad \bar{Y} = \frac{Y}{N} = \frac{1}{N}(y_1 + y_2 + y_3 + \ldots + Y_N)$$

The variability in the measured characteristics among the population units is given by S_y^2

$$S_y^2 = \frac{1}{N-1}\left[\sum_{1}^{N} y_i^2 - \frac{(\sum_{1}^{N} y_i)^2}{N}\right]$$

Now, if we draw a sample of n units from the N units in the population, we can define:

$$\text{Sample Total} \quad : \quad y = \sum_{1}^{n} y_i = y_1 + y_2 + \ldots + y_n$$

$$\text{Sample Mean} \quad : \quad \bar{y} = \frac{y}{n} = \frac{1}{n}(y_1 + y_2 + \ldots + y_n)$$

and the variance per unit in the sample is given by:

$$s_y^2 = \frac{1}{n-1}\left[\sum_{1}^{n} y_i^2 - \frac{(\sum_{1}^{n} y_i)^2}{n}\right]$$

If the same method of measurement of the desired characteristics is employed both for the population units and the sample units, the absolute value of the precision of the sample mean is given by:

$$|d| = |\bar{y} - \bar{Y}|$$

Generally, the population mean $\bar{Y}$ is not known and the main purpose of sampling is to get an estimate of $\bar{Y}$ from the sample and also to have a measure of precision of that estimate. Now we know that in SRS we can produce N_{C_n} samples (or n units) from a population of N units, and we can have a series of N_{C_n} sample means $\bar{y}$'s. In the case of a SRS selection, it has been proved that the average of all possible sample means $\bar{y}$'s is equal to $\bar{Y}$ and thus $\bar{y}$ is an unbiased estimate of $\bar{Y}$. It has also been proved that in the case of SRS selection, the variance of $\bar{y}$ is given by:

$$V(\bar{y}) = \left(1 - \frac{n}{N}\right) \frac{S_y^2}{n}$$

or,

$$= S^2_{y/n} \quad \text{if } {}^{n}/_{N} \text{ is negligible.}$$

The standard error of the sample mean $\bar{y}$ is given by:

$$S_{\bar{y}} = +\sqrt{V(\bar{y})} = \sqrt{\left(1 - \frac{n}{N}\right)} \frac{S_y}{\sqrt{n}}$$

or,

$$= \frac{S_y}{\sqrt{n}}, \quad \text{when } \frac{n}{N} \text{ is negligible.}$$

$S_{\bar{y}}$ measures the degree of scatter of possible sample means around $\bar{Y}$. The smaller it is, the probability of a large deviation of $\bar{y}$ from $\bar{Y}$ will be small. For $n > 30$, it has been shown that at 95% probability level, the population mean $\bar{Y}$ will lie in the interval,

$$\bar{y} - 1.96\, S_{\bar{y}} < \bar{Y} < \bar{y} + 1.96\, S_{\bar{y}}$$

Thus we see that $S_{\bar{y}}$ provides a measure of precision of the sample estimate.

We generally do not know S_y in order to calculate $S_{\bar{y}}$. In SRS, an unbiased estimate of S_y is provided by s_y.

Thus an unbiased estimate of the standard error of the sample mean $\bar{y}$ is given by:

$$s^2_{\bar{y}} = v(\bar{y}) = \left(1 - \frac{n}{N}\right) \frac{s_y^2}{n}, \quad \text{and} \quad s_{\bar{y}} = +\sqrt{s^2_{\bar{y}}}$$

The relative precision of $\bar{y}$ is given by:

$$CV(y) = \frac{S_y}{\bar{Y}}$$

and an unbiased estimate of $CV(\bar{y})$ is given by:

$$cv(\bar{y}) = \frac{s_{\bar{y}}}{\bar{y}}$$

3.1 Estimation of population total and precision

In SRS sample, the estimate of population total is given by

$$\hat{Y} = N \cdot \bar{y}$$

and the estimated variance of $\hat{Y}$ is

$$v(\hat{Y}) = N^2 \, v(\bar{y})$$

and the estimated standard error of $\hat{Y}$ is

$$s_{\hat{Y}} = \sqrt{v(\hat{Y})} \ .$$

The estimated coefficient variation of $\hat{Y}$ is

$$cv(\hat{Y}) = \frac{s_{\hat{Y}}}{\hat{Y}}$$

Example 3.1

In a landing site, 30 boats land their catch on a particular day, and the catches (y_i) of 10 boats selected at random are examined. Estimate the total catch of the day and its standard error and coefficient of variation: N = 30; n = 10.

Sample boat	Catch (kg)	
	y_i	y_i^2
1	12	144
2	8	64
3	4	16
4	6	36
5	0	0
6	16	256
7	5	25
8	9	81
9	11	121
10	9	81

We have: $\sum y_i = 80$; $\sum y_i^2 = 824$.

The various estimates are:

(a) $\bar{y} = \frac{\Sigma y_i}{n} = \frac{80}{10} = 8$ kg ; $\hat{Y} = N\bar{y} = 30 \times 8 = 240$ kg

(b) $s_y^2 = \frac{1}{n-1} \left[\sum_i y_i^2 - \frac{(\Sigma y_i)^2}{n}\right] = \frac{1}{9} [824 - 640] = 20.44$

(c) $v(\hat{Y}) = N^2 \, v(\bar{y}) = N^2 \cdot (1 - \frac{n}{N}) \frac{s_y^2}{n} = 30^2 \times 1.3626$

(d) $s_{\hat{Y}} = \sqrt{v(\hat{Y})} = 30 \times \sqrt{1.3626} = 35.1$

(e) $cv(\hat{Y}) = \frac{s_{\hat{Y}}}{\hat{Y}} = \frac{35.1}{240} = 14.6\%$

In Section 3 we have seen:

$$cv(\bar{y}) = \frac{s_{\bar{y}}}{\bar{y}} = \frac{s_y}{\bar{y}} \sqrt{\frac{N-n}{Nn}} = cv(y) \sqrt{\frac{N-n}{Nn}}$$

Therefore,

$$\frac{cv(\bar{y})}{cv(y)} = \sqrt{\frac{N-n}{Nn}} = \sqrt{\left(\frac{1}{n} - \frac{1}{N}\right)}$$

If,

$$\frac{cv(\bar{y})}{cv(y)} = \frac{1}{g}$$

then,

$$\frac{1}{g} = \sqrt{\frac{1}{n} - \frac{1}{N}} \quad \text{and} \quad n = \frac{Ng^2}{N + g^2}$$

When N is large,

$$\frac{cv(\bar{y})}{cv(y)} = \frac{1}{\sqrt{n}}$$

or,

$$n = \left[\frac{cv(y)}{cv(\bar{y})}\right]^2$$

Now, for large N, at 95% probability level, the population mean will lie within the interval $\bar{y} \pm 1.96\, s_{\bar{y}}$ or roughly within $y \pm 2\, s_{\bar{y}}$. Therefore, $a = \frac{2s_{\bar{y}}}{\bar{y}} \times 100 = 2\, cv(\bar{y})$ represents percentage accuracy of the mean at 5% significance level.

Thus, the sample size n required for an a% accuracy of the mean at 5% significance level is given by:

$$n = \frac{[cv(y)]^2}{(a/2)^2} = \left[\frac{200 \times s_y}{a\bar{y}}\right]^2$$

Example 3.2a

In a survey sample n = 18 gave a mean of $\bar{y} = 589.44$ kg and $s_y = 531.79$. How many units would be needed if it were desired to estimate at a 5% significance level, the estimated mean (a) within 10%, (b) within 5%, and (c) within 1% of the population mean.

We have,

$$cv(y) = \frac{531.79}{589.44} \times 100 = 90.22 .$$

Therefore,

(a) Number of units required for getting $\bar{y}$ with an accuracy of 10% is,

$$n = \left[\frac{200 \times 531.79}{10 \times 589.44}\right]^2 = 326 \text{ units}$$

(b) For an accuracy of 5%,

$$n = \left[\frac{200 \times 531.79}{5 \times 589.44}\right] = 1302 \text{ units}$$

(c) For an accuracy of 1%,

$$n = \left[\frac{200 \times 531.79}{1 \times 589.44}\right] = 32{,}558 \text{ units}$$

Example 3.2b

In Example 3.1a, if we had derived an estimate of $\bar{y}$ with a cv of 5%, what size of sample would be needed.

We have, $cv(y) = \frac{\sqrt{20.44}}{8} \times 100 = 56.50$ percent

$N = 30$

$cv(\bar{y}) = 5.00$ percent

Therefore,

$$g = \frac{56.5}{5.0} = 11.3$$

and, $$n = \frac{Ng^2}{N + g^2} = \frac{30 \times (11.3)^2}{30 + (11.3)^2} = \frac{30 \times 127.69}{30 + 127.69} = 24.29;$$ i.e. 24 boats

4. Estimation of Proportions and their uses

Let there be N units in the population of which N_i belongs to i-class, so that the proportion belonging to class i is: $P_i = \frac{N_i}{N}$. We want to estimate N_i and P_i from a simple random of n units, in which n_i is in class i so that $p_i = \frac{n_i}{n}$.

It has been shown that an unbiased estimate $\hat{P}_i$ of p_i is given by p_i, so that $\hat{P}_i = p_i = \frac{n_i}{n}$, and an unbiased estimate of N_i (where N_i is the number in the class i in the population) is given by: $\hat{N}_i = N \cdot p_i$.

An unbiased estimate of variance of p_i is given by:

$$v(p_i) = \frac{N-n}{N} \frac{p_i q_i}{n-1}, \quad \text{where } q_i = 1 - p_i . \tag{4.1}$$

When $\frac{n}{N}$ is small, i.e. n is small compared to N, or N is very large,

$$v(p_i) = \frac{p_i q_i}{n-1}, \text{ or simply } v(p_i) = \frac{p_i q_i}{n} \text{ if n is fairly large.} \tag{4.2}$$

An unbiased estimate of the variance of $\hat{N}_i$ is given by:

$$v(\hat{N}_i) = v(Np_i) = N^2 v(p_i) . \tag{4.3}$$

If the magnitude of N is itself an estimate, the estimated variance of N_i is given by:

$$v(\hat{N}_i) = N^2 v(p_i) + p_i^2 \text{var}(\hat{N}) . \tag{4.4}$$

Example 4.1

A random sample of 82 boats were taken out of 820 boats. It was found that 32 were using lines. Estimate the proportion and number of boats using lines.

Hence, $N = 820$; $n = 82$; $n_i = 32$

$\therefore$ $p_i = \frac{32}{82} = \cdot 39$ and $v(p_i) = \frac{p_i q_i}{n-1} = \frac{\cdot 39 \times \cdot 61}{82-1} = 0.0029$

and, $N_i = 820 \times \cdot 39 = 320$

$v(N_i) = 820^2 v(p_i) = 820^2 \times 0.0029 = 1949.96$

$\therefore$ $\sqrt{v}(N_i) = 44.15$

Example 4.2

The number of cods landed was 2,000. A sample of 100 cods were taken and their ages determined, and the distribution is as follows:

Age	8	9	10	11	12	Total
Number (n_i)	14	54	7	19	6	100

Find out the estimated number of cods in each age group in the total landings and the variance of these estimates.

Here we have: $N = 2000$; $n = n_1 + n_2 + n_3 + n_4 + n_5 = 100$

Age	8	9	10	11	12	Total
n_i	14	54	7	19	6	100
p_i	·14	·54	·07	·19	·06	
q_i	·86	·46	·93	·81	·94	
$p_i\ q_i$	·12	·25	·07	·15	·06	
$v(p_i) = \frac{p_i\ q_i}{n}$	0012	0025	0007	0015	0006	(equation 4.2 for large n)
$\hat{N}_i = N\ p_i$	280	1080	140	380	2000	
$v(\hat{N}_i) = N^2 v(p_i)$	4800	10000	2800	6000	2400	
$s(N_i) = \sqrt{v(\hat{N}_i)}$	69.3	100.0	52.9	77.4	49.0	

5. Stratified Sampling

It has been seen that in simple random sampling the variance of mean $v(\bar{y})$ depends, apart from the sample size n, on the variability of the characteristics in the population, i.e. on S_y^2. If the population is heterogeneous, i.e. measurements vary considerably from one unit to another, then by using auxiliary information, it may be possible to divide it into sub- populations (or strata), each of which is internally homogeneous.

Let us suppose that there are N units in the population and these are stratified into k strata with N_i unitsin the i^{th} stratum. Let a sample of n units be drawn, of which n_i are from the i^{th} stratum. Let y_{ij} be the measurement of the j^{th} unit in the i^{th} stratum.

Then we have the following:

$$\bar{y}_i = \text{sample mean of the } i^{th} \text{ stratum} = \frac{1}{n_i} \sum_{j}^{n_i} y_{ij}$$

$$\hat{Y}_i = \text{estimate of total of the } i^{th} \text{ stratum} = N_i\ \bar{y}_i$$

and,
$$\hat{Y}_{st} = \text{estimate of population total} \qquad (5.1)$$
$$= \text{sum of strata total estimates}$$
$$= \sum_{1}^{k} N_i\ \bar{y}_i$$

We also have,

$$\bar{y}_{st} = \text{estimated population mean} = \frac{\hat{Y}_{st}}{N} = \frac{1}{N} \sum_{1}^{k} N_i\ \bar{y}_i \qquad (5.2)$$

The unbiased estimates of variances are:

$$v(\hat{Y}_{st}) = \sum_i N_i^2 \, v(\bar{y}_i) = \sum_i N_i^2 \left(\frac{1}{n_i} - \frac{1}{N_i}\right) s_i^2 \qquad (5.3)$$

where, $$s_i^2 = \frac{1}{n_i - 1}\left[\sum_j^{n_i} y_{ij}^2 - \frac{(\sum_j y_{ij})^2}{n_i}\right]$$

and, $$v(\bar{y}_{st}) = \frac{1}{N^2}\left[\sum N_i^2 \left(\frac{1}{n_i} - \frac{1}{N_i}\right) s_i^2\right] \qquad (5.4)$$

If the sampling fraction $\frac{n_i}{N_i}$ is negligible for all strata, then we have:

$$v(\hat{Y}_{st}) = \sum N_i^2 \frac{s_i^2}{n_i} \qquad (5.5)$$

and, $$v(\bar{y}_{st}) = \frac{1}{N^2} \sum N_i^2 \frac{s_i^2}{n_i} = \sum W_i^2 \frac{s_i^2}{n_i} \qquad (5.6)$$

where, $$W_i = \frac{N_i}{N}$$

Example 5

Out of 200 boats in a district, 70 were engaged in line fishing, 120 in gillnet fishing, and 10 in beach-seine fishing. For the purpose of estimating catch, 5 line fishing boats, 7 gillnet boats, and 3 beach-seine boats were selected, and their catches in tons for the month of January were noted as follows:

Line boats	:	2, 3, 4, 5, 6
Gillnet boats	:	7, 8, 9, 10, 12, 13, 11
Beach-seine boats	:	20, 23, 26

What was the estimated total catch in the district in January and the variance of the estimates? What is the mean catch per boat and its variance?

Strata	N_i	n_i	$\bar{y}_i$	s_i^2	$N_i \bar{y}_i$	$N_i^2(\frac{1}{n_i} - \frac{1}{N_i})$	$N_i^2(\frac{1}{n_i} - \frac{1}{N_i})s_i^2$
1	70	5	4	2.50	280	910	2275.00
2	120	7	10	4.67	1200	1937.14	9046.44
3	10	3	23	9.00	230	23.33	209.97
Total:	200	15	-	-	1710	-	11530.97

$$\hat{Y}_{st} = \sum N_i \bar{y}_i = 1710 \text{ tons}$$

$$\bar{y}_{st} = \frac{1710}{200} = 8.55 \text{ tons}$$

$$v(\hat{Y}_{st}) = 11{,}530.97 \quad \text{and} \quad s_{\hat{Y}_{st}} = \sqrt{v(\hat{Y}_{st})} = 107.38$$

There, $$cv(\hat{Y}_{st}) = \frac{107.38}{710} = 0.06 \text{ ; i.e., } 6\%.$$

$$v(\bar{y}_{st}) = \frac{11{,}530.97}{40{,}000} = .2883 \quad \text{and} \quad s_{\bar{Y}_{st}} = .54$$

Note: If there was no stratification, and we had chosen a simple random selection of 15 units, and their catches were as in *Example 5*, we would have:

$$\bar{y} = \frac{\Sigma y}{n} = \frac{159}{15} = 10.06 \text{ tons}; \quad \text{and} \quad s_y^2 = \frac{1}{n-1}\left[\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right]$$

and, $\hat{Y} = 10.06 \times 200 = 2{,}012$ tons

Therefore,

$$v(\bar{y}) = \left(\frac{1}{n} - \frac{1}{N}\right)s_y^2 = .0616 \times 38.82 = 2.39$$

$$s_{\bar{y}} = 1.55$$

and, $v(\hat{Y}) = N^2\, v(\bar{y}) = 40{,}000 \times 2.39 = 95{,}600$

$$s_{\hat{Y}} = 309.19$$

Therefore,

$$cv(\hat{Y}) = \frac{309.19}{2{,}012} = .15 \quad \text{(i.e. 15\%)}$$

Clearly, by stratification, we have obtained an estimate with lower $cv(\hat{Y})$ than in the case of a simple random selection.

5.1 Sample Size in Different Strata

In *Example 5*, we selected a sample of 15 units, and the allocation of number of units in the different strata was done arbitrarily.

Now, when the sampling fraction is negligible, we know from equation (5.5) that variance of the population total is given by:

$$v(\hat{Y}_{st}) = \sum N_i^2 \frac{s_i^2}{n_i}$$

This equation suggests two methods of allocation of n among the different strata:

(a) Proportional allocation:
In this method, n_i is proportional to N_i. If within-stratum variances are equal, the method gives the smallest sampling variance, i.e., the most efficient estimates. Generally, the proportional allocation is used when information on strata variances are not available.

(b) Optimum allocation:
When the within-strata variances differ greatly from stratum to stratum, the proportional allocation no longer provides best estimates. In such cases, it is better that the sampling fraction is taken proportional to the stratum standard deviation.

For further details on these, one is referred to books of sampling designs (e.g., Yates, Bazigos - 1974).

Example 5.1

The following catches (kg) were obtained in 18 hauls of a trawl survey:

200, 440, 600, 640, 700, 800, 900, 1020, 1600, 1920

20, 10, 340, 400, 720

40, 100, 160

(a) If the trawl net covered 40 ha per haul and if 50% of all fish in its path was caught and the total survey area was 6×10^6ha, estimate the total abundance of fish.

(b) If the first 10 hauls were taken in depths 0-20 m, the next 5 in depths 20-40 m, and the last three in depths over 40 m and the areas of the depth zones are 1×10^6, 2×10^6 and 3×10^6ha respectively, what will be the estimate of abundance?

(c) Find the variances of the above two estimates.

Solution

(a) Unstratified Sample

Let $\bar{y}$ be the mean catch, and if a is the area swept by each haul, the catch per hectare is $\bar{y}/a$. Since the net catches only 50%, i.e. the catchability coefficient q is $\frac{1}{2}$, the density of stock per hectare is: $\frac{\bar{y}}{aq}$.

Therefore, estimated abundances for the survey area A are:

$$B = \frac{A}{aq} \cdot \bar{y}$$

and, $$v(B) = \left(\frac{A}{aq}\right)^2 \text{var. } \bar{y} = \left(\frac{A}{aq}\right)^2 \frac{\text{var. } y}{n}$$

where n is the number of sample hauls.

Now we have,

$\bar{y} = 589.44$ kg; $v(y) = 282{,}805.56$

$A = 6\times10^6$ ha; $a = 40$ ha; and $q = \frac{1}{2}$

Therefore, $$\hat{B} = \frac{6\times10^6}{40\times\frac{1}{2}} \times 589.44 \text{ kg} = 176{,}830 \text{ tons}$$

and, $$v(\hat{B}) = \left(\frac{6\times10^6\times2}{40}\right)^2 \times \frac{282{,}805.56}{18}$$

$$= 10^{12} \times 1{,}414.03 \text{ kg}^2$$

$$s(\hat{B}) = \sqrt{v(\hat{B})} = 10^6\times37.60 \text{ kg} = 37{,}600 \text{ tons}$$

$$cv(\hat{B}) = \frac{s(\hat{B})}{\hat{B}} \times 100 = 21.26\%$$

(b) Stratified Sample

In this case, $\hat{B} = \sum \hat{B}_i = \sum \frac{A_i}{a_i q_i} \bar{y}_i$,

and, $v(\hat{B}) = \sum (\frac{A_i}{a_i q_i})^2 \text{ var. } \bar{y}_i$

The numerical calculations may be done conveniently in a tabular fashion:

Stratum	n_i	$\bar{y}_i$ (kg)	s_i^2	A_i	$\frac{A_i}{qa}$	$B_i = \frac{A_i \bar{y}_i}{qa}$ (tons)	$(\frac{A_i}{qa})^2 \frac{s_i^2}{n_i}$ (kg^2)
1	10	882	272,306.67	1×10^6	50×10^3	44,100	$10^{12} \times$ 66.08
2	5	298	87,620.00	2×10^6	100×10^3	29,800	$10^{12} \times$175.24
3	3	100	3,600.00	3×10^6	150×10^3	15,000	$10^{12} \times$ 27.00
					$\hat{B}$ =	88,900	$10^{12} \times$270.32

and, $v_{st}(\hat{B}) = 10^{12} \times 270.32 \text{ kg}^2$

and, $s(\hat{B}_{str}) = \sqrt{10^{12} \times 270.32} = 16,440$ tons

Therefore, $cv(\hat{B}_{str}) = \frac{16,440}{88,900} \times 100 = 18.47\%$

Ratio Estimation

This is another method in which use is made of auxiliary information to increase the precision. Let us suppose we have selected at random n units out of N units in the population and for each of these selected units we have measured (x,y), where y is the survey variate and x is another correlated variate. The population total of x-variate is known to be:

$$X = \sum_1^N x_i ,$$

but y may not be known for each unit of the population except for those in the sample. In this case, an estimate of the population total Y of the survey variate is given by: $\hat{Y}_{rat} = \hat{R} X$, where the estimate R is obtained from the sample as:

$$\hat{R} = \frac{\sum_1^n y_i}{\sum_1^n x_i}$$

The variance of the ratio estimate $\hat{Y}_{rat}$ is given by:

$$v(\hat{Y}_{rat}) = \frac{N \cdot (N-n)}{n} [s_y^2 + \hat{R}^2 s_x^2 - 2 \hat{R} s_x s_y \cdot r] \qquad (6.1)$$

where, r is the estimated coefficient of correlation between x and y.

Example 6.1

There are 50 landing centres in a country where shrimp trawlers land. The shrimp trawlers are registered and the total from the Registration Record is known to be 280. Now, 5 landing centres are selected at random and the catch (y) and the number of trawlers (x) at each of the 5 landing centres are obtained. Make a ratio estimate Y_{rat} of the total landings by the shrimp trawlers in the country.

We have,

Landing Centres: Total - N = 50
Sample - n = 5

Trawlers: Total - X = 280

Sample landing centres	No.of trawlers (x)	Catch (y) (tons)	x^2	y^2	xy
1	2	22	4	484	44
2	10	95	100	9,025	950
3	7	62	49	3,844	434
4	3	33	9	1,089	99
5	8	83	64	6,889	664
TOTAL:	30	295	226	21,331	2,191

We have,

$$s_x^2 = \frac{1}{n-1}\left[\sum x^2 - \frac{(\Sigma x)^2}{n}\right] = 11.5$$

$$s_y^2 = \frac{1}{n-1}\left[\sum y^2 - \frac{\Sigma y)^2}{n}\right] = 981.5$$

$$s_{xy} = \frac{1}{m-1}\left[\sum xy - \frac{\Sigma x \cdot \Sigma y}{n}\right] = 105.25$$

$$r = \frac{s_{xy}}{\sqrt{s_x^2 \cdot s_y^2}} = .99$$

and,

$$\hat{R} = \frac{\sum_1^n y_i}{\sum_1^n x_i} = \frac{295}{30} = 9.83$$

Therefore, $\hat{Y}_{rat} = \hat{R}\,X = 9.83 \times 280 = 2752.40$ tons

and from equation (6.1),

$$v(\hat{Y}_{rat} = \frac{50 \times 45}{5}\left[981.50 + (9.83)^2 \times 11.5 - 2 \times 9.83 \times .99 \times \sqrt{11.5 \times 981.5}\right]$$

$$= 11,578.50$$

and, $s_{\hat{Y}_{rat}} = \sqrt{11,578.50} = 107.60$

Therefore, $cv(Y_{rat}) = \frac{107.60}{2752.40} = .04$ (i.e. 4%)

7. Unequal Probability Sampling

We have seen that by stratification and ratio estimation we can increase the precision of estimate. Another technique used for this purpose is pps sampling, i.e. where the sampling units are selected with probabilities proportional to their sizes. This is widely used in cases where sampling of clusters is preferred to direct sampling of individual units, the reasons being that it is economical to sample a fixed number of individual units when they are in clusters and that sometimes reliable frame of individual units are not available.

7.1 Method of Selection

Suppose there are 10 landing sites with number of boats at each landing sites shown in Col.2. We want to select 3 sites with pps.

Landing site (1)	No.of boats (2)	Cumulative Total (3)	Allotted numbers (4)	Selected Random No. or Fishing Site (5)
1	12	12	001 - 012	
2	5	17	013 - 017	Random No. 011
3	20	37	018 - 037	Fishing Site 01
4	2	39	038 - 039	Random No. 027
5	30	69	040 - 069	Fishing Site 03
6	15	84	070 - 084	Random No. 064
7	8	92	085 - 092	Fishing Site 05
8	6	98	093 - 098	
9	8	106	099 - 106	
10	14	120	107 - 112	
	120			

Column 3 is the cumulative total. Now each landing site is given a number proportional to its size. Thus the landing site 1 gets 12 numbers, 001-012, allotted to it, the landing centre 5 gets 30 numbers from 040-069 allotted to it, and so on. Then we use the random number table and select 3 numbers between 1 and 120. These selected numbers are: 011, 027 and 064. The corresponding fishing sites selected are: 01, 03 and 05.

It may be noted that in this method of selection a unit with a larger size has a higher chance of selection than a unit of a smaller size.

7.2 Method of Estimation

Let there be N primary sampling units (fishing sites) and let x_i be the number of secondary units (boats) in the i^{th} landing site. If n primary units are selected with pps, then the probability p_i of selecting the i^{th} unit in the sample is: $p_i = \frac{x_i}{\sum x_i}$.

The estimate of the Population Total Y is given by:

$$\hat{Y} = \frac{1}{n} \sum_{i} \frac{y_i}{p_i} \qquad (7.2.1)$$

where y_i is the measurement of the i^{th} unit in the sample; and the estimated variance of Y is given by:

$$v(\hat{Y}) = \frac{1}{n(n-1)} \sum_{i=1}^{n} \left(\frac{y_i}{p_i} - \hat{Y}\right)^2 \qquad (7.2.2)$$

$$= \frac{1}{n(n-1)} \left[\sum t_i^2 - \frac{(\Sigma t_i)^2}{n}\right]$$

where, $t_i = \frac{y_i}{p_i}$

Example 7.2

There are 20 fishing sites in a district. The number of boats at each centre is known, i.e. x_i = number of boats at the i^{th} centre is known, and therefore $X = \Sigma x_i$ is known to be 496. Four fishing sites are selected out of 20 fishing sites with pps. In the table below, Col.1 gives the 4 fishing sites selected in the sample, Col.2 gives the number of boats (x) in these sites, and Col.3 gives the landings at these sites during a month. Estimate the total monthly landings $\hat{Y}$ and $v(\hat{Y})$.

Sample sites	No.of boats (x_i)	Landings (tons) (y_i)	$p_i = \frac{x_i}{x}$	$t_i = \frac{y_i}{p_i}$	t^2
(1)	(2)	(3)	(4)	(5)	(6)
1	22	81	0.0443	1,828	3341,584
2	30	118	0.0605	1,950	3802,500
3	30	118	0.0605	1,950	3802,500
4	42	170	0.0847	2,007	4028,049
TOTAL:				7,735	14974,633

Using (7.2.1), we get: $\hat{Y} = \frac{1}{4}\sum_{1}^{4} t_i = \frac{7735}{4} = 1934$ tons

Using (7.2.2), we get: $v(\hat{Y}) = \frac{1}{12}\left[14974{,}633 - \frac{(7735)^2}{4}\right] = 1423$

$cv(\hat{Y}) = \frac{\sqrt{1423}}{1934} = .019$ (i.e. 1.9%)

8. Two-Stage Sampling

In two-stage sampling, a sample of first-stage units are chosen first, and in each of the selected first-stage units, a further sample of survey units is chosen. A simple random selection may be made for the first-stage units or they can be selected with probability proportional to their sizes.

8.1 Selection of first-stage units at random

Let us have:

N = Number of first-stage units

n = Number of first-stage sample units

M_i = Number of survey units in the i^{th} first-stage unit

m_i = Number of survey units selected in the i^{th} first-stage unit

$f_i = \frac{n}{N}$ = First-stage sampling fraction

$f_{2i} = \frac{m_i}{M_i}$ = Second-stage sampling fraction in the i^{th} primary unit

The unbiased estimate of the population total of the survey characteristics (y) is given by:

$$\hat{Y} = \frac{N}{n} \sum M_i \bar{y}_i \qquad (8.1.1)$$

where, $\bar{y}_i = \frac{1}{m_i} \sum_{j=1}^{m_i} y_{ij}$ and $\hat{Y}_i = M_i \bar{y}_i$

and its estimated variance is given by:

$$v(\hat{Y}) = \frac{N(N-n)}{n} \cdot \frac{1}{n-1} \sum_{1}^{n} [\hat{Y}_i - \frac{\Sigma \hat{Y}_i}{n}]^2 + \frac{N}{n} \sum \frac{M_i (M_i - m_i)}{m_i} s_i^2$$

$$= \frac{N(N-n)}{n} \frac{1}{n-1} [\sum_{1}^{n} \hat{Y}_i^2 - \frac{(\sum_{1}^{n} \hat{Y}_i)^2}{n}] + \frac{N}{n} \sum \frac{M_i (M_i - m_i)}{m_i} s_i^2$$

where, $s_i^2 = \frac{1}{m_i - 1} [\sum_{j=1}^{m_i} y_{ij}^2 - \frac{(\sum_{j=1}^{m_i} y_{ij})^2}{m_i}]$

Example 8.1

Let there be 8 fishing sites (N = 8). We first select n = 3 fishing sites at random and for each fishing site we select 3 traps and measure their catch. The number of traps existing at each selected fishing site and the catches of each selected trap are shown below. Calculate the estimated total catch of trap fisheries and its variance.

Sample sites	1	2	3
No.of traps at each site (M_i)	6	9	7
No.of traps selected (m_i)	3	3	3
Catches of selected traps	13	5	12
	9	7	8
	6	10	13
Sample Total	28	22	33
s_i^2	12.3	6.3	7.0

Estimated total landings,

$$\hat{Y} = \frac{N}{n} \sum M_i \bar{y}_i$$

$$= \frac{8}{3} (6 \times \frac{28}{3} + 9 \times \frac{22}{3} + 7 \times \frac{33}{3})$$

$$= 531$$

$$v(\hat{Y}) = \frac{8}{3}\cdot\frac{5}{2}\times 221 + \frac{8}{3}\left[\left(\frac{6\times 3}{3}\times 12.3 + \left(\frac{9\times 6}{3}\times 6.3\right) + \left(\frac{7\times 4}{3}\ 7.0\right)\right]\right.$$

$$= 1473 + 673.3 = 2146.6$$

$$cv(\hat{Y}) = \frac{\sqrt{2146.6}}{531}\cdot 100 = 8.73\%$$

It may be noted that the contribution 1473.3 to $v(\hat{Y})$ is due to difference in the obtained catches between the fishing sites and this is much greater than 673.3 which is due to difference among second-stage units within the first-stage units.

8.2 Selection of first-stage units with pps

The estimated catch in the i^{th} fishing site is given by:

$$\hat{Y}_i = \frac{M_i}{m_i}\sum_{j}^{m_i} y_{ij}$$

The unbiased estimate of the population total is given by:

$$\hat{Y} = \frac{1}{n}\sum_{i=1}^{n}\frac{\hat{Y}_i}{p_i} = \frac{1}{n}\sum_{i=1}^{n} t_i$$

The variance of Y is given by:

$$v(Y) = \frac{1}{n}\cdot\frac{1}{n-1}\left[\sum t_i^2 - \frac{(\Sigma t_i)^2}{n}\right]$$

Example 8.2

Three fishing sites were chosen with pps and within each sample fishing site a simple random sample of boats were selected. In the table below we give catches (in kg) of selected sample. Calculate $\hat{Y}$ and $cv(\hat{Y})$.

Sample fishing site	p_i	$\frac{M_i}{m_i} = P_{2i}$	$\sum_{j=1}^{m_i} y_{ij}$	$\hat{Y}_i$	$t_i = \frac{\hat{Y}_i}{p_i}$	t_i^2
1	$\frac{30}{1000}$	6	120	720	24,000	576,000
2	$\frac{50}{1000}$	5	200	1000	20,000	400,000
3	$\frac{10}{1000}$	2	110	220	22,000	484,000
TOTAL:					66,000	1460,000

We therefore have,

$$\hat{Y} = \frac{1}{n}\sum\frac{Y_i}{p_i} = \frac{1}{n}\sum t_i = \frac{66,000}{3} = 22,000 \text{ kg}$$

and,

$$v(\hat{Y}) = \frac{1}{3}\cdot\frac{1}{2}\left[1460,000 - \frac{(66,000)^2}{3}\right] = 1333,333$$

and,

$$cv(\hat{Y}) = \frac{\sqrt{1333,333}}{22,000}\ 100 = 5.25\%$$

APPENDIX II

Table of Random Numbers

	First Thousand									
	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40
1	23 15	75 48	58 01	83 72	59 93	76 24	97 08	86 95	23 03	67 44
2	05 54	55 50	43 10	53 74	35 08	90 61	18 37	44 10	96 22	13 43
3	14 87	16 03	50 32	40 43	62 23	50 05	10 03	22 11	54 38	08 34
4	38 97	67 49	51 94	05 17	58 53	78 80	59 01	94 32	42 87	16 95
5	97 31	26 17	18 99	75 53	08 70	94 25	12 58	41 54	88 21	05 13
6	11 74	26 93	81 44	33 93	08 72	32 79	73 31	18 22	64 70	68 50
7	43 36	12 88	59 11	01 64	56 23	93 00	90 04	99 43	64 07	40 36
8	93 80	62 04	78 38	26 80	44 91	55 75	11 89	32 58	47 55	25 71
9	49 54	01 31	81 08	42 98	41 87	69 53	82 96	61 77	73 80	95 27
10	36 76	87 26	33 37	94 82	15 69	41 95	96 86	70 45	27 48	38 80
11	07 09	25 23	92 24	62 71	26 07	06 55	84 53	44 67	33 84	53 20
12	43 31	00 10	81 44	86 38	03 07	52 55	51 61	48 89	74 29	46 47
13	61 57	00 63	60 06	17 36	37 75	63 14	89 51	23 35	01 74	59 93
14	31 35	28 37	99 10	77 91	89 41	31 57	97 64	48 62	58 48	69 19
15	57 04	88 65	26 27	79 59	36 82	90 52	95 65	46 35	06 53	22 54
16	09 24	34 42	00 68	72 10	71 37	30 72	97 57	56 09	29 82	76 50
17	97 95	63 50	18 40	89 48	83 29	52 23	08 25	21 22	53 26	15 87
18	93 73	25 95	70 43	78 19	88 85	56 67	16 68	26 95	99 64	45 69
19	72 62	11 12	25 00	92 26	82 64	35 66	65 94	34 71	68 75	18 67
20	61 02	07 44	18 45	37 12	07 94	95 91	73 78	66 99	53 61	93 78
21	97 83	98 54	74 33	05 59	17 18	45 47	35 41	44 22	03 42	30 00
22	89 16	09 71	92 22	23 29	06 37	35 05	54 54	89 88	43 81	63 61
23	25 96	68 82	20 62	87 17	96 65	02 82	35 28	62 84	91 95	48 83
24	81 44	33 17	19 05	04 95	48 06	74 69	00 75	67 65	01 71	65 45
25	11 32	25 49	31 42	36 23	43 86	08 62	49 76	67 42	24 52	32 45

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